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Eveleigh et al.

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(54) **SYSTEM AND METHOD FOR PROVIDING TEMPERED FLUID**

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(73) Assignee: **Magarl, LLC**, Naples, FL (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 192 days.

(21) Appl. No.: **13/540,345**

(22) Filed: **Jul. 2, 2012**

(65) **Prior Publication Data**

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Related U.S. Application Data

(63) Continuation of application No. 11/493,164, filed on Jul. 26, 2006, now Pat. No. 8,209,796, which is a continuation-in-part of application No. 11/180,380, filed on Jul. 13, 2005, now Pat. No. 7,657,950.

(60) Provisional application No. 60/592,710, filed on Jul. 30, 2004.

(51) **Int. Cl.**
A61H 33/00 (2006.01)
A61H 35/02 (2006.01)

(52) **U.S. Cl.**
CPC ***A61H 33/60*** (2013.01); ***A61H 33/0095*** (2013.01); ***A61H 35/02*** (2013.01); *Y10T 137/87684* (2015.04)

(58) **Field of Classification Search**
CPC A61H 35/02
USPC 4/620, 598
See application file for complete search history.

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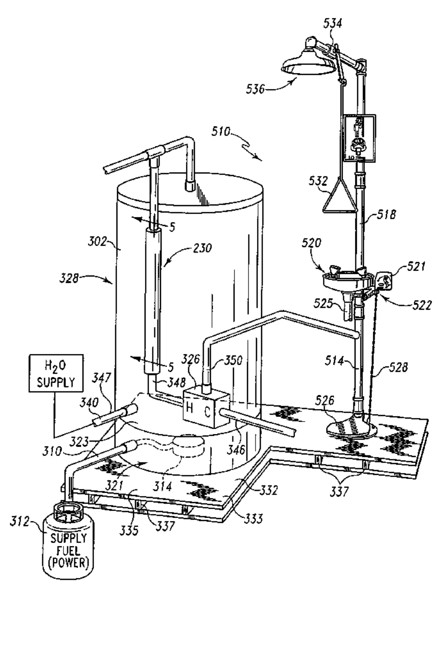
Primary Examiner — Huyen Le

(74) *Attorney, Agent, or Firm* — John V. Daniluck; Bingham Greenebaum Doll LLP

(57) **ABSTRACT**

The present invention is directed to methods and apparatus for tempering the temperature of a liquid in a fluid conducting system. More particularly, the invention relates to tempering the temperature of water supplied to a fixture from a water heater in a fluid conducting system. In some embodiments, the invention includes a restrictor for decreasing the fluid pressure in one of the hot inlet or cold inlet of the mixing valve.

12 Claims, 24 Drawing Sheets



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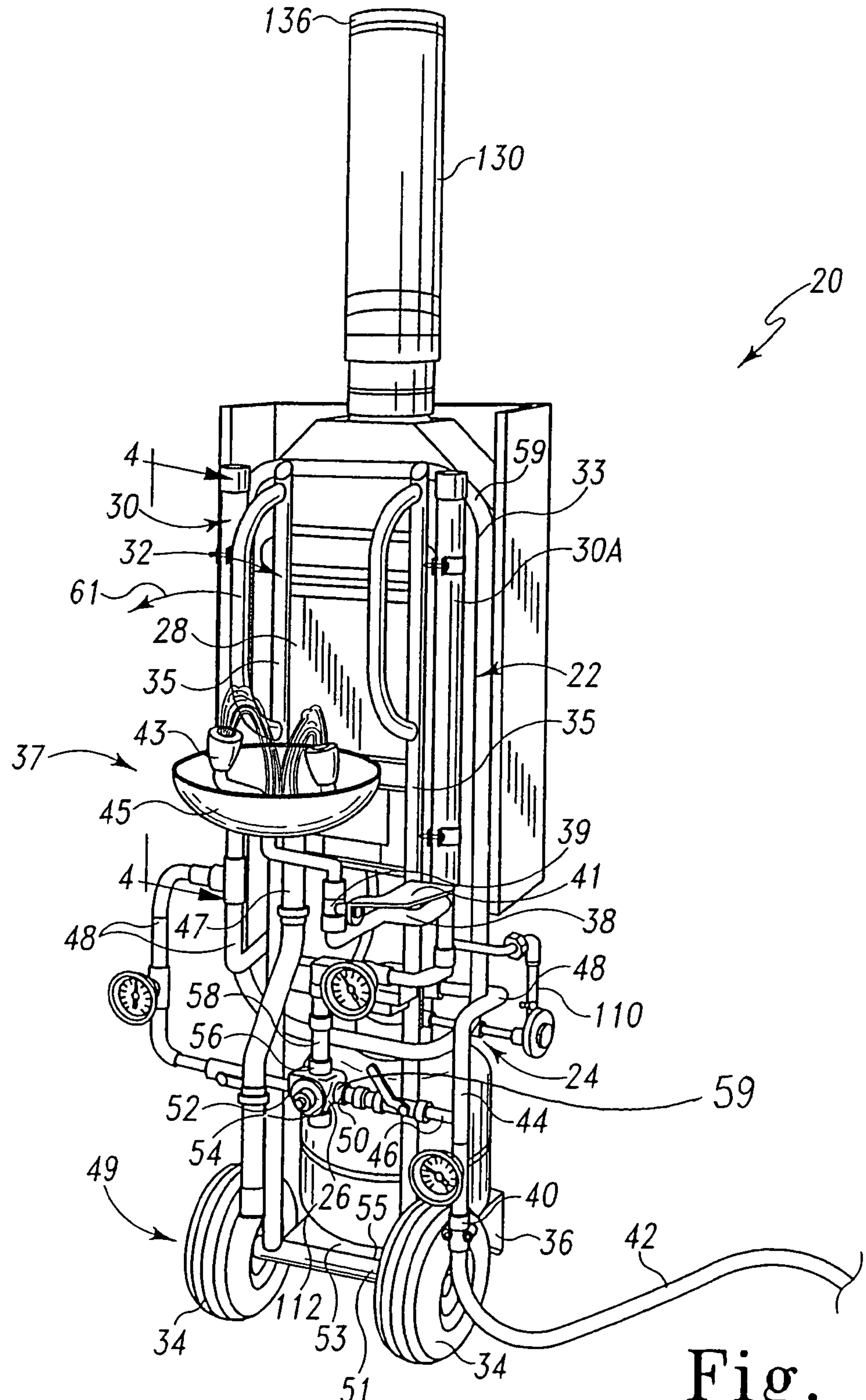
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42
34

Fig. 1

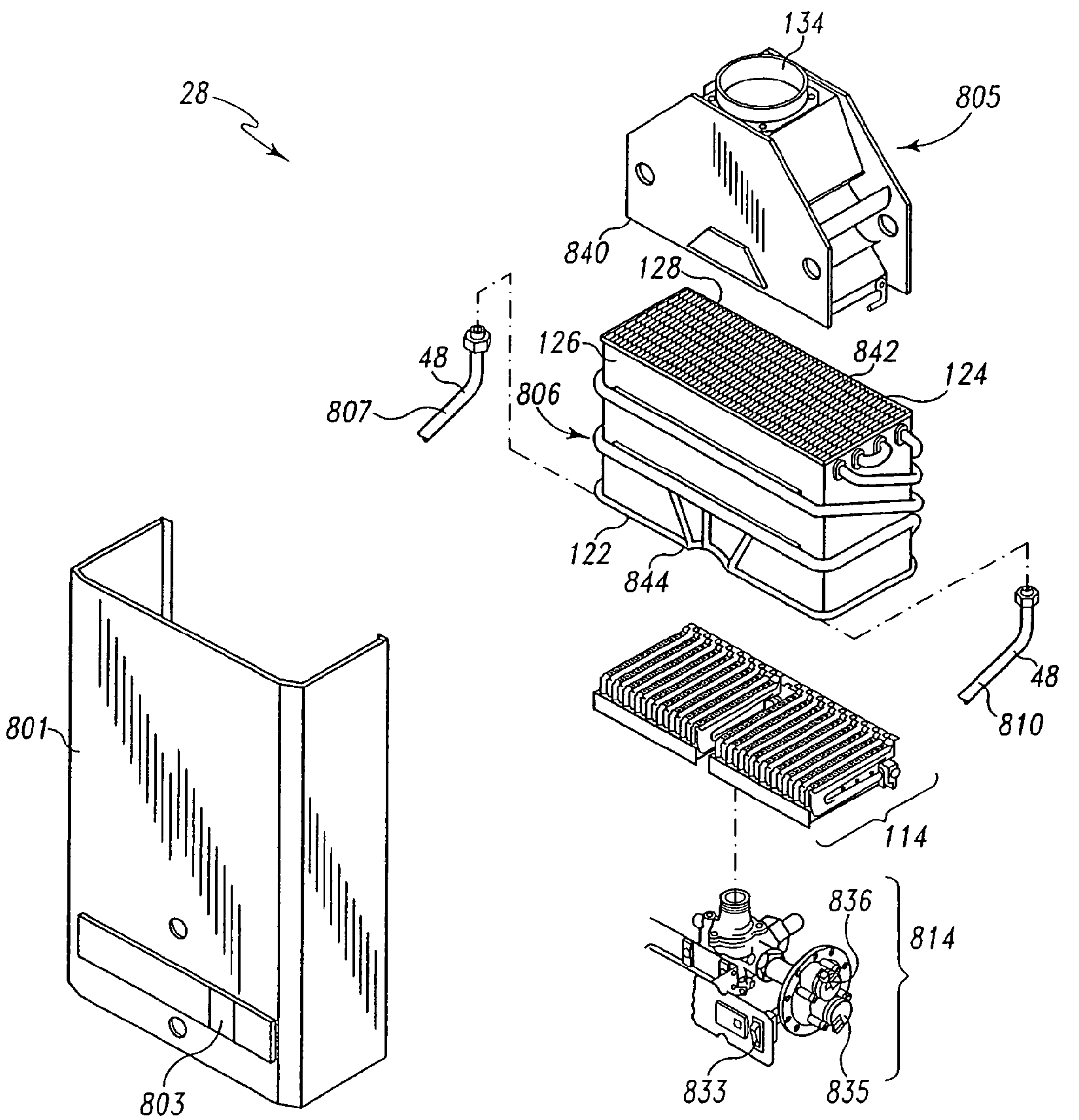
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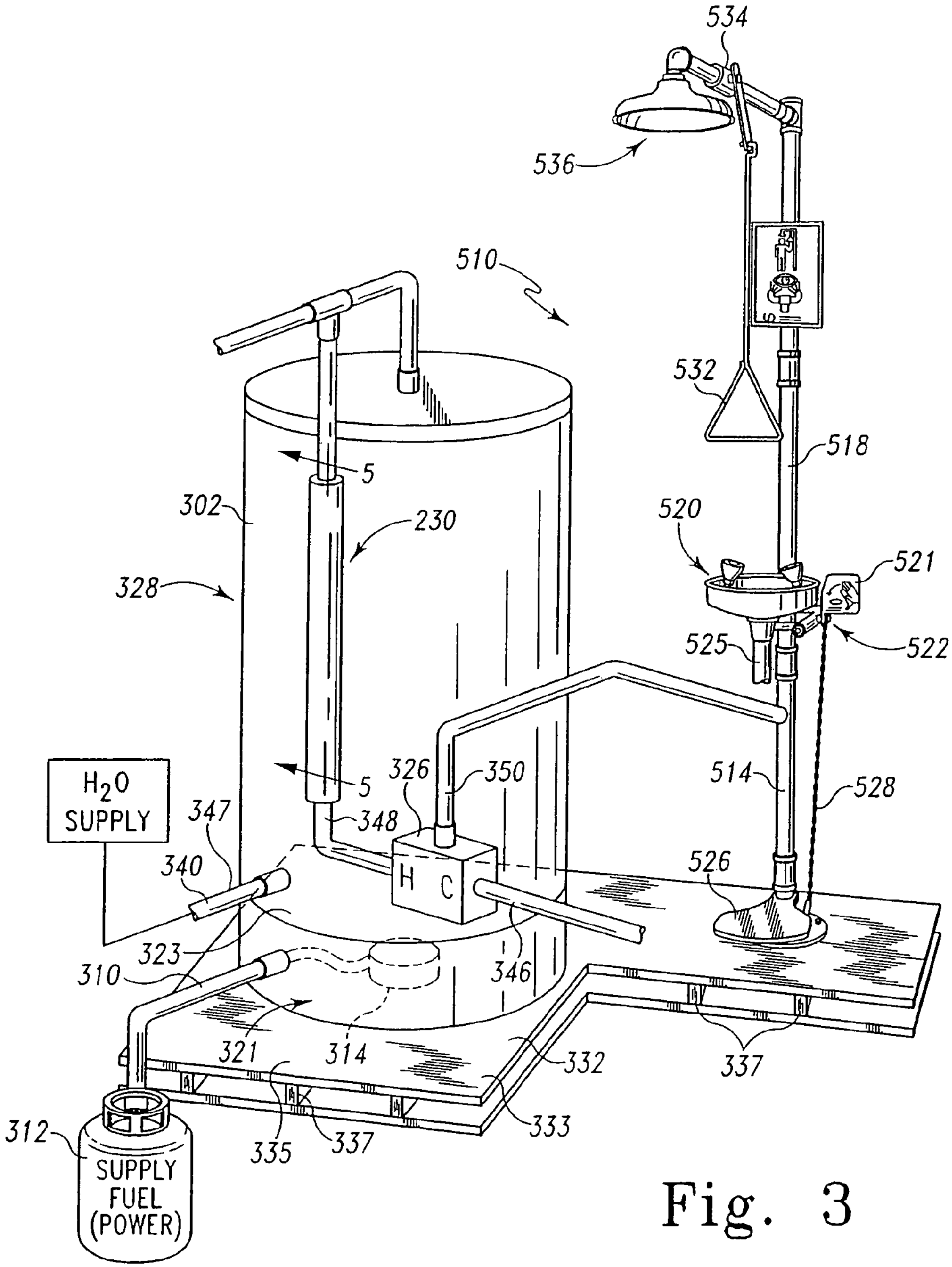
Fig. 2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347
348
340
526
H
C
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346
321
314
332
337
312
335
337
333
SUPPLY FUEL (POWER)

Fig. 3

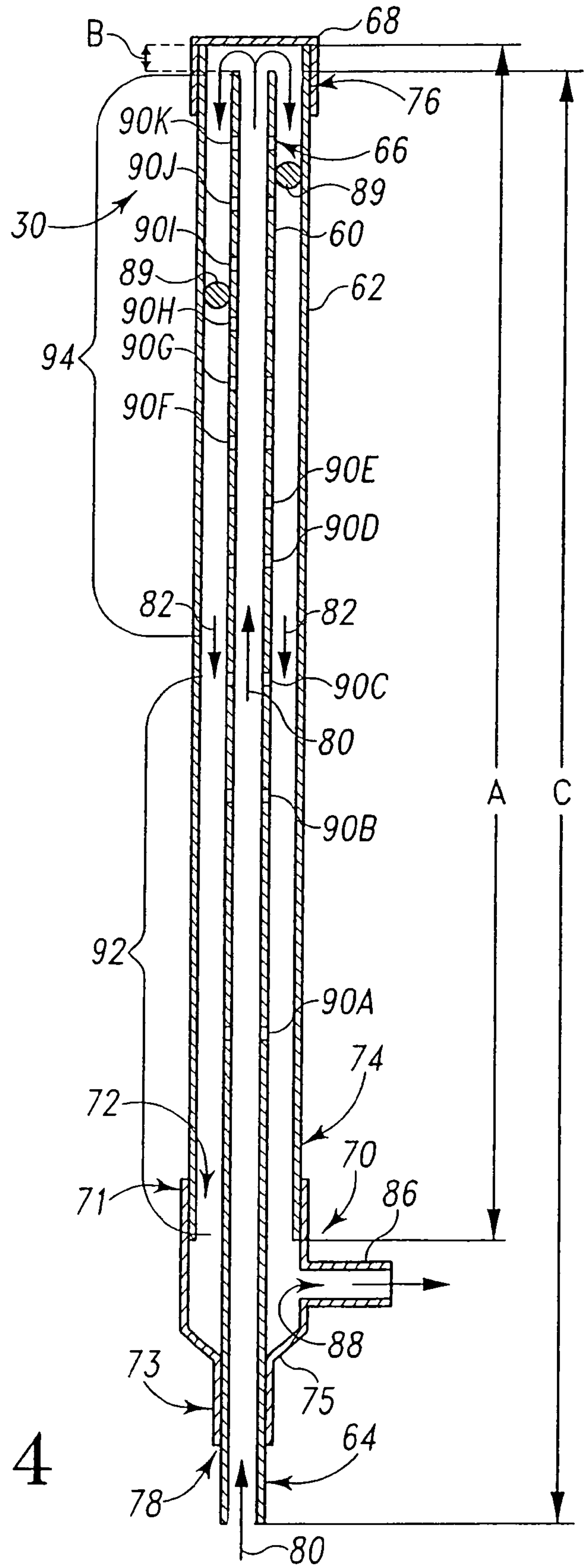
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Fig. 4

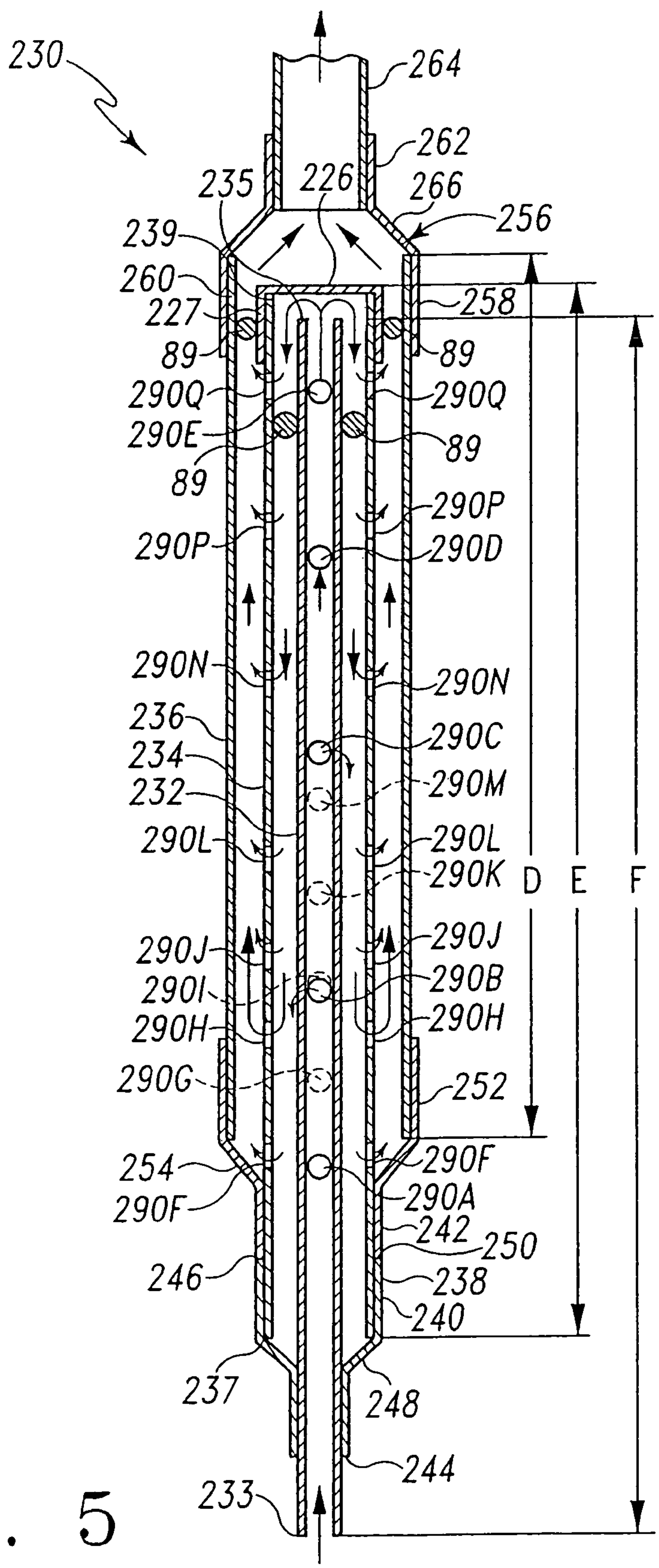

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Fig. 5

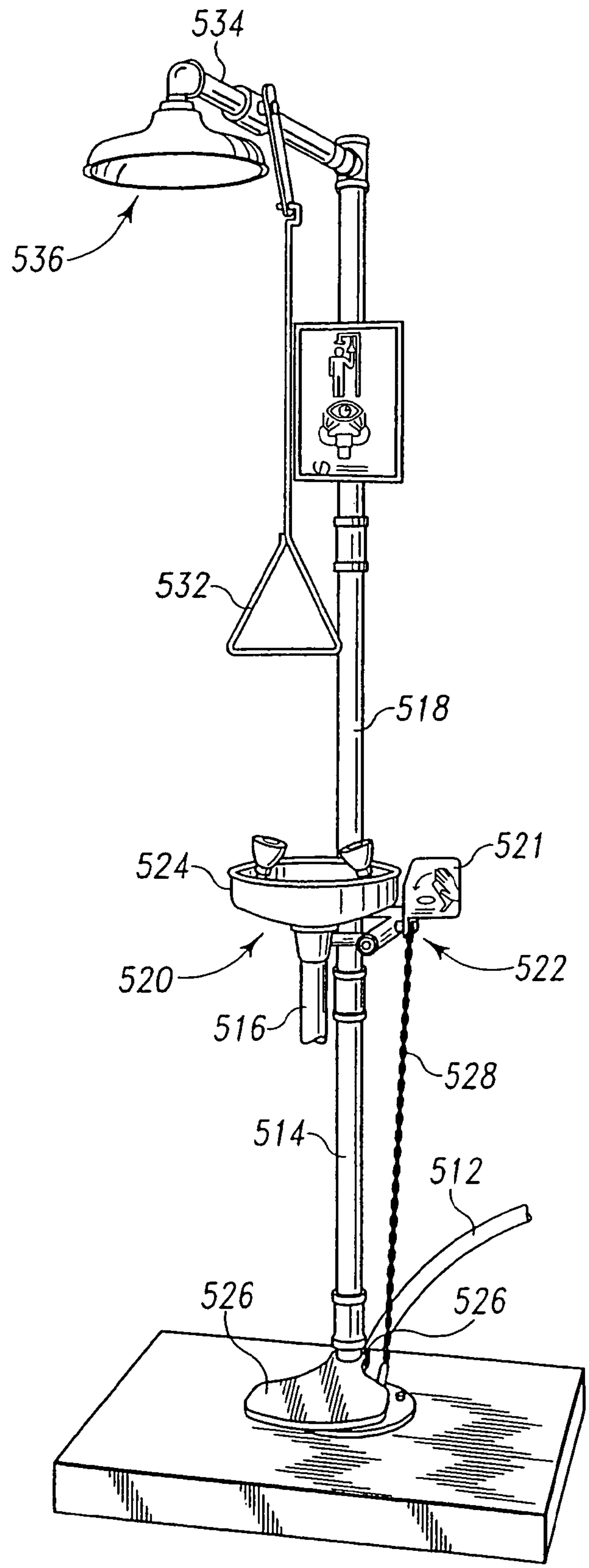
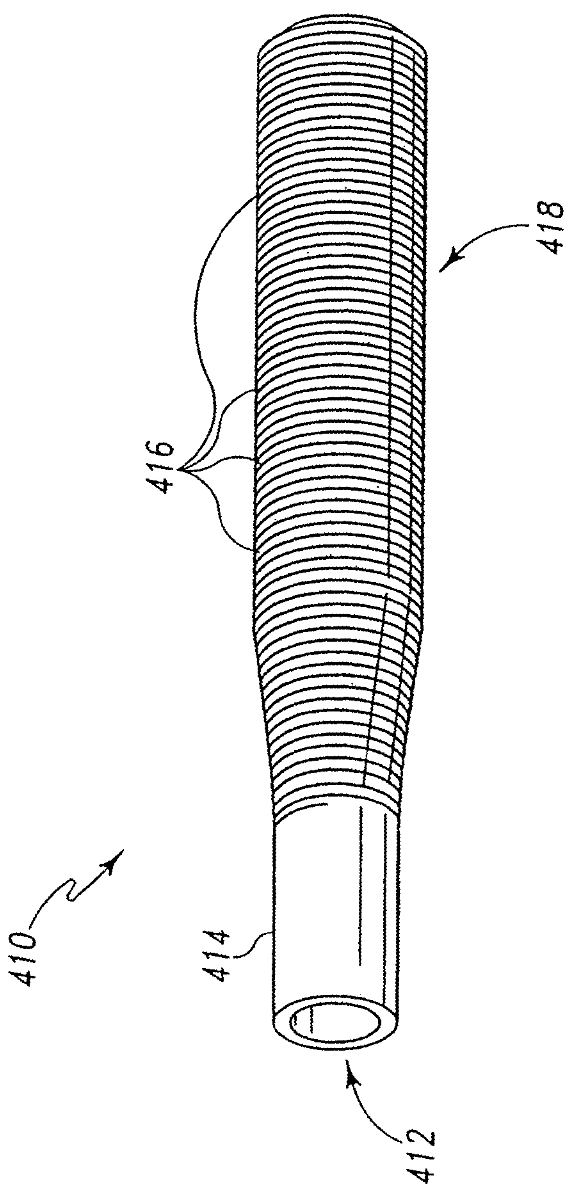


Fig. 6



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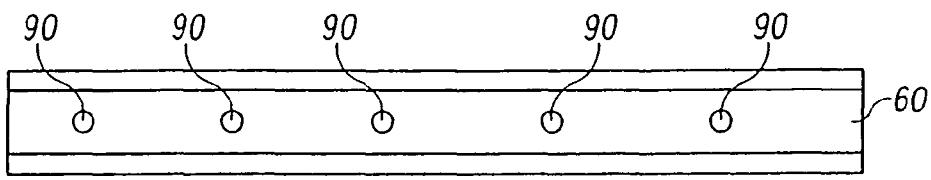


Fig. 8

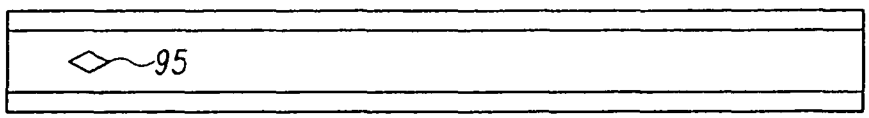


Fig. 9

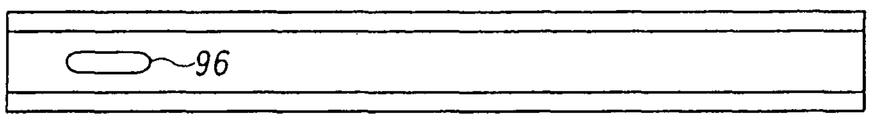
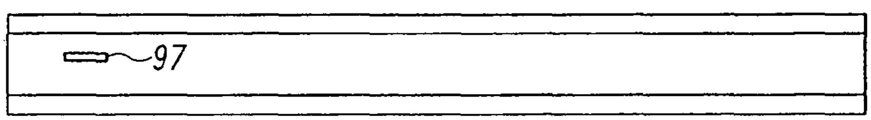


Fig. 10



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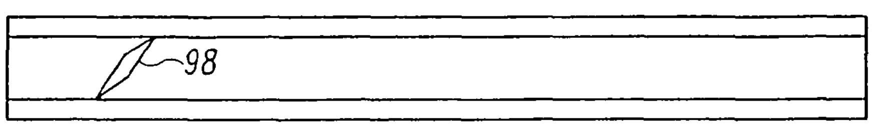

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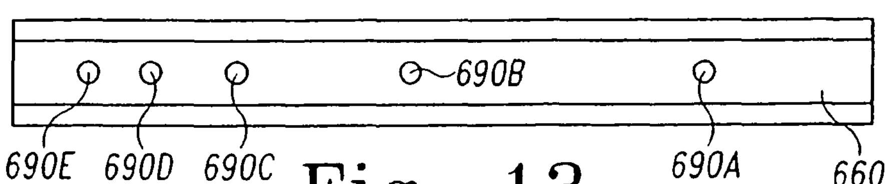


Fig. 13

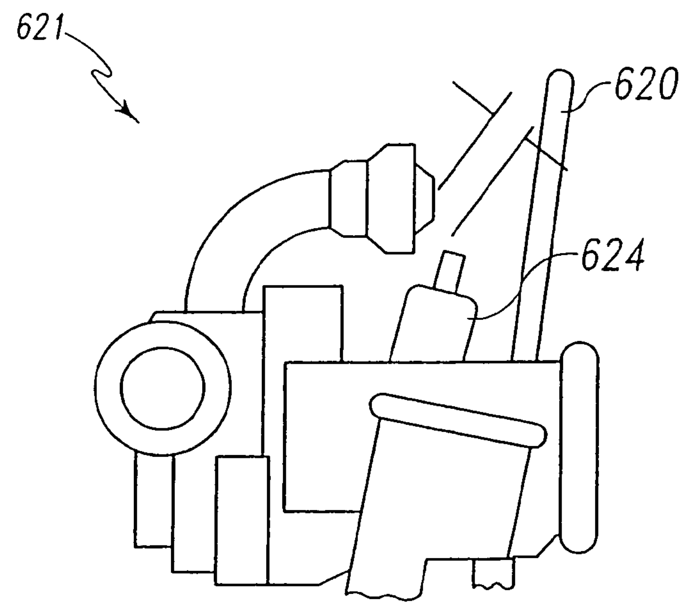
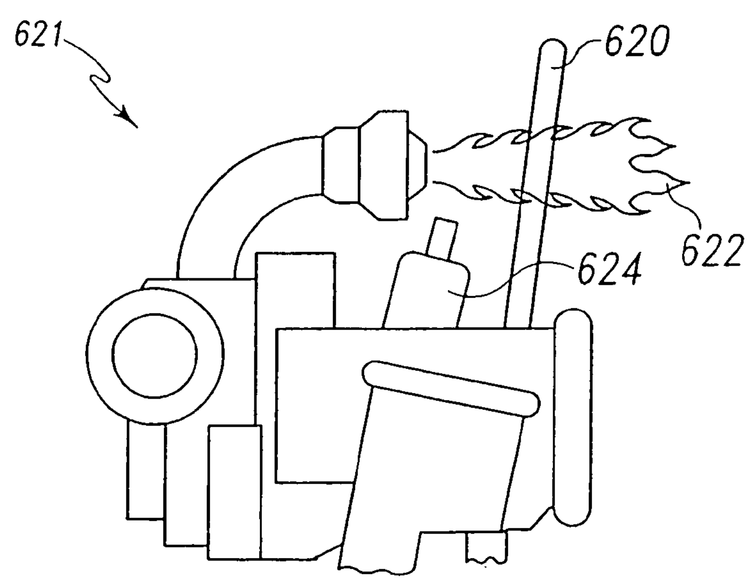


Fig. 14



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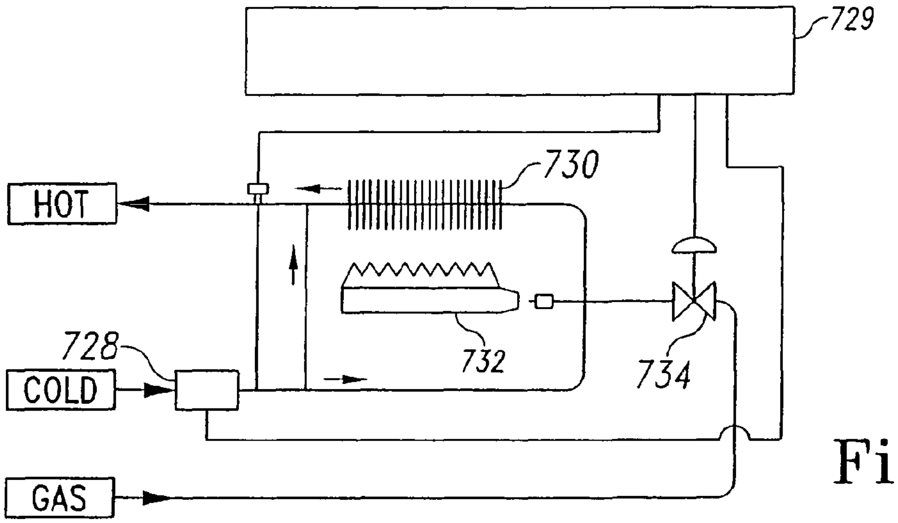

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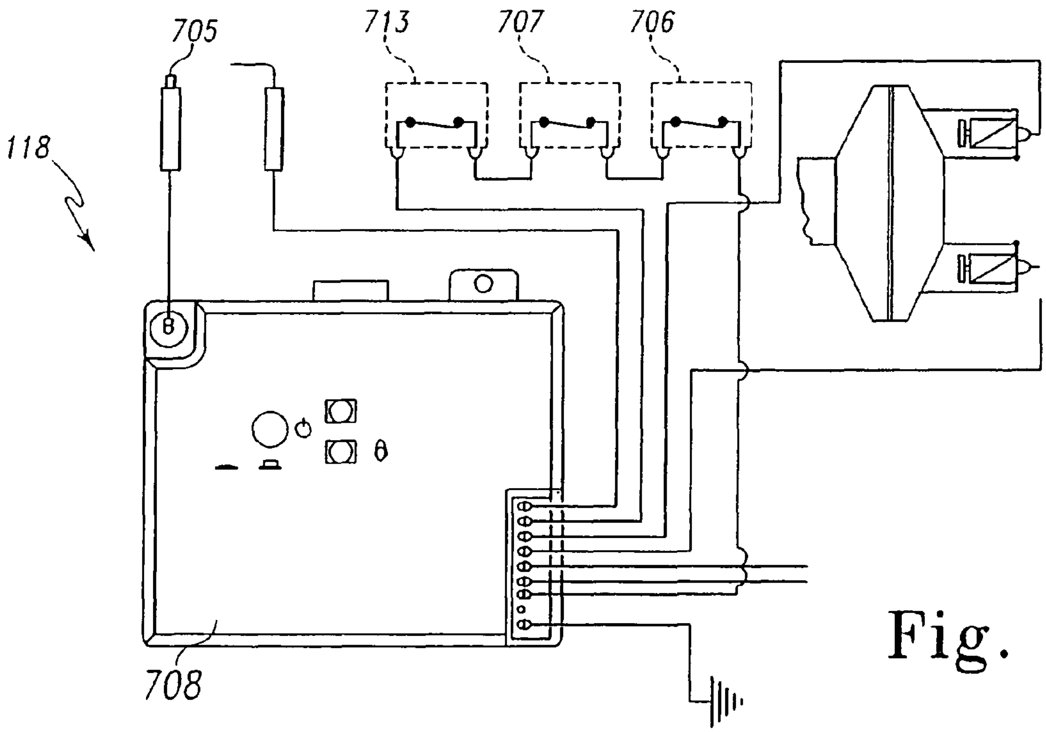


Fig. 17

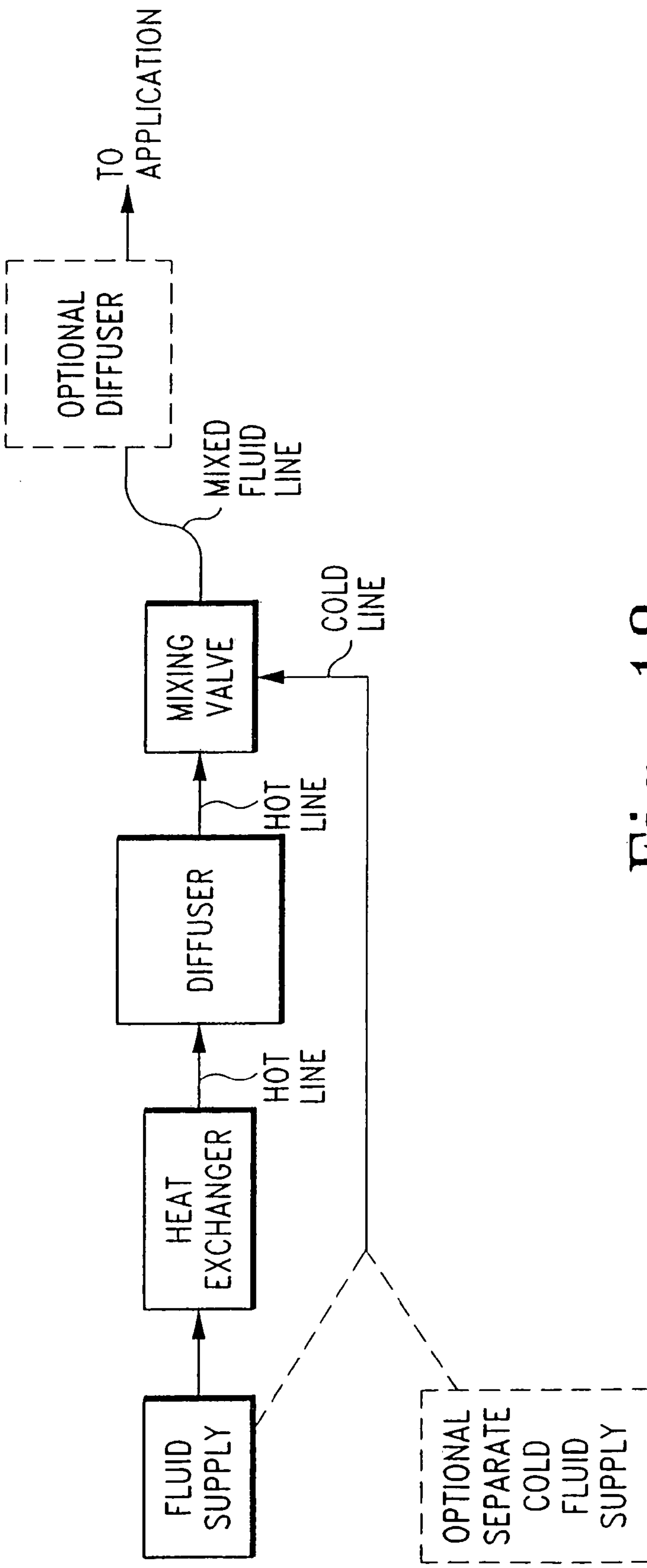
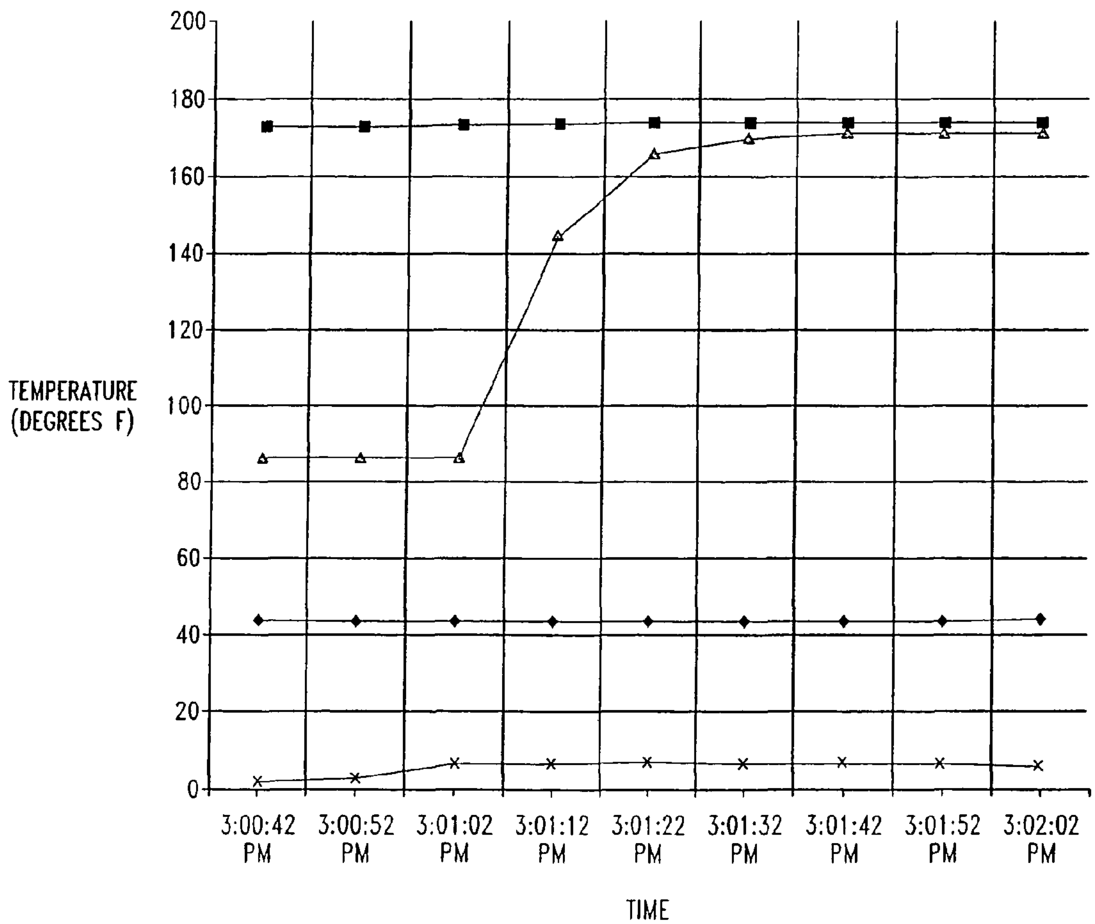

TO APPLICATION
OPTIONAL DIFFUSER
MIXED FLUID LINE
COLD LINE
MIXING VALVE
HOT LINE
DIFFUSER
HOT LINE
HEAT EXCHANGER
FLUID SUPPLY
OPTIONAL SEPARATE COLD FLUID SUPPLY

Fig. 18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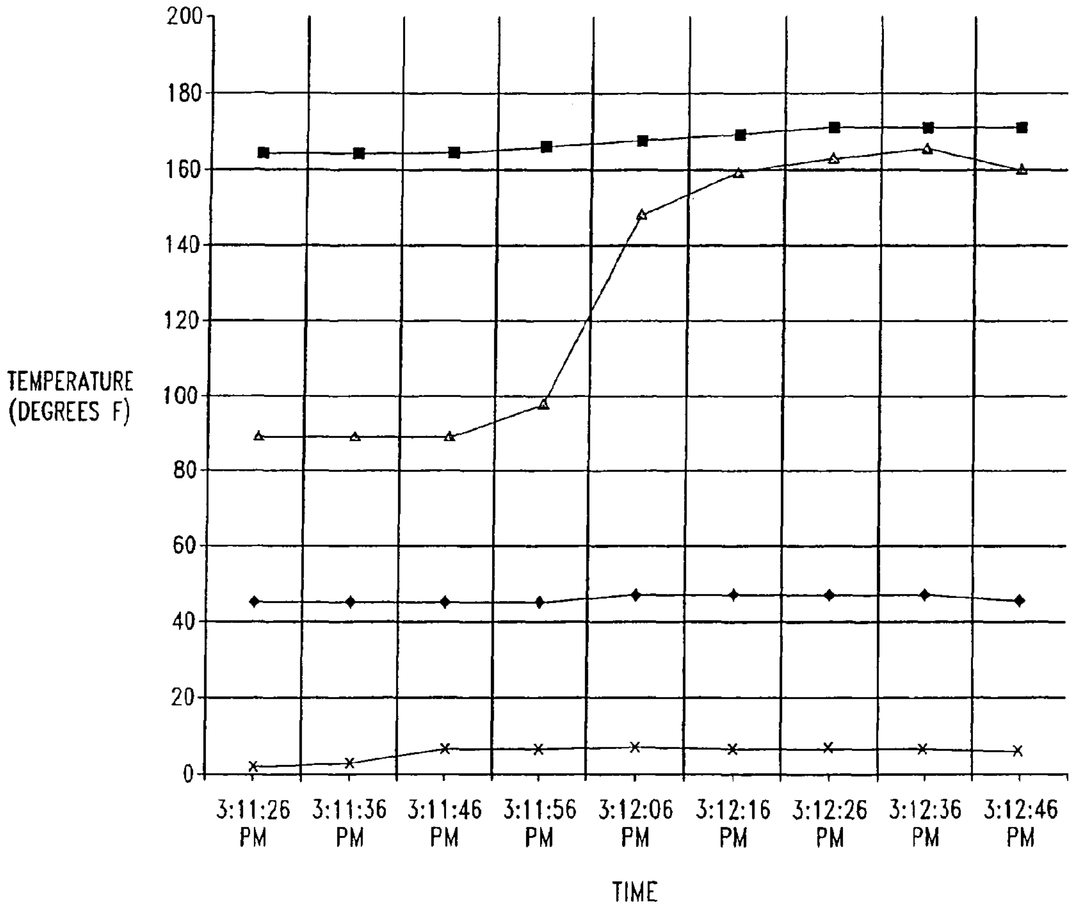
TIME

Fig. 19A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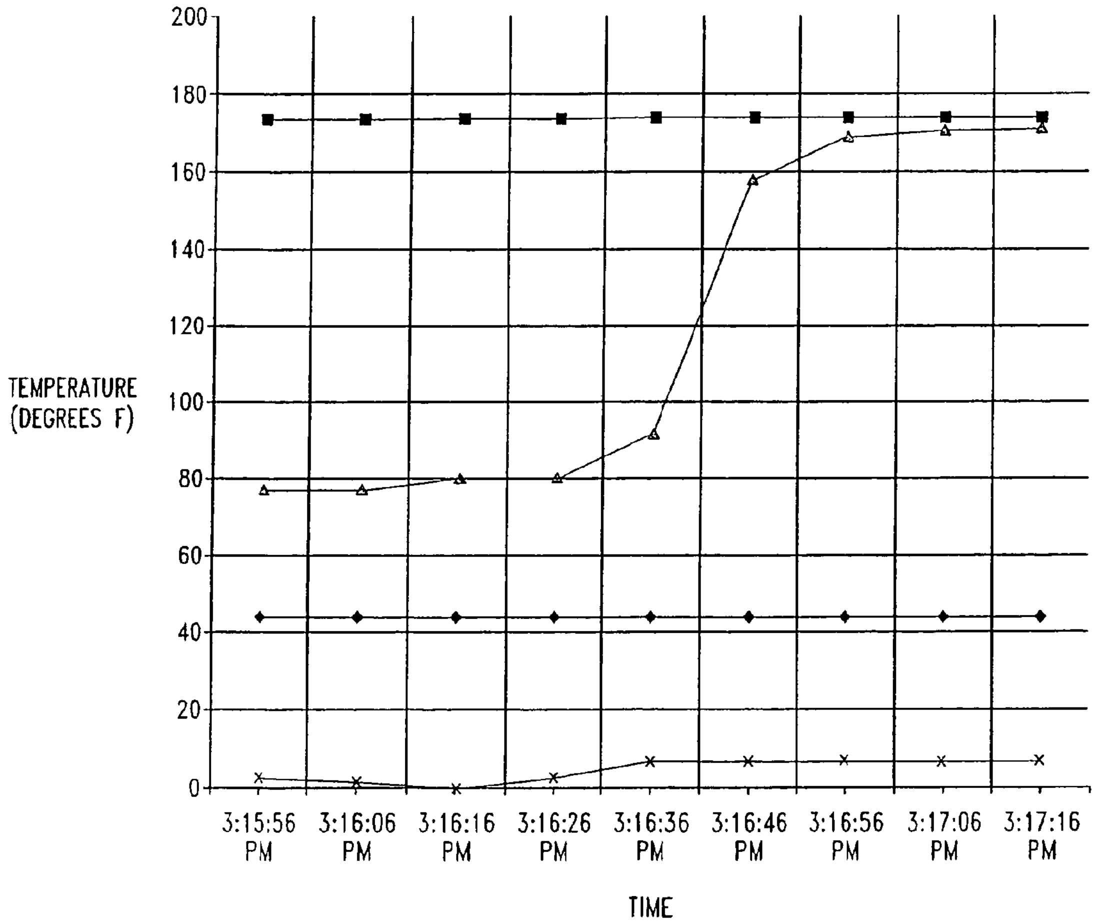
TIME

Fig. 19B



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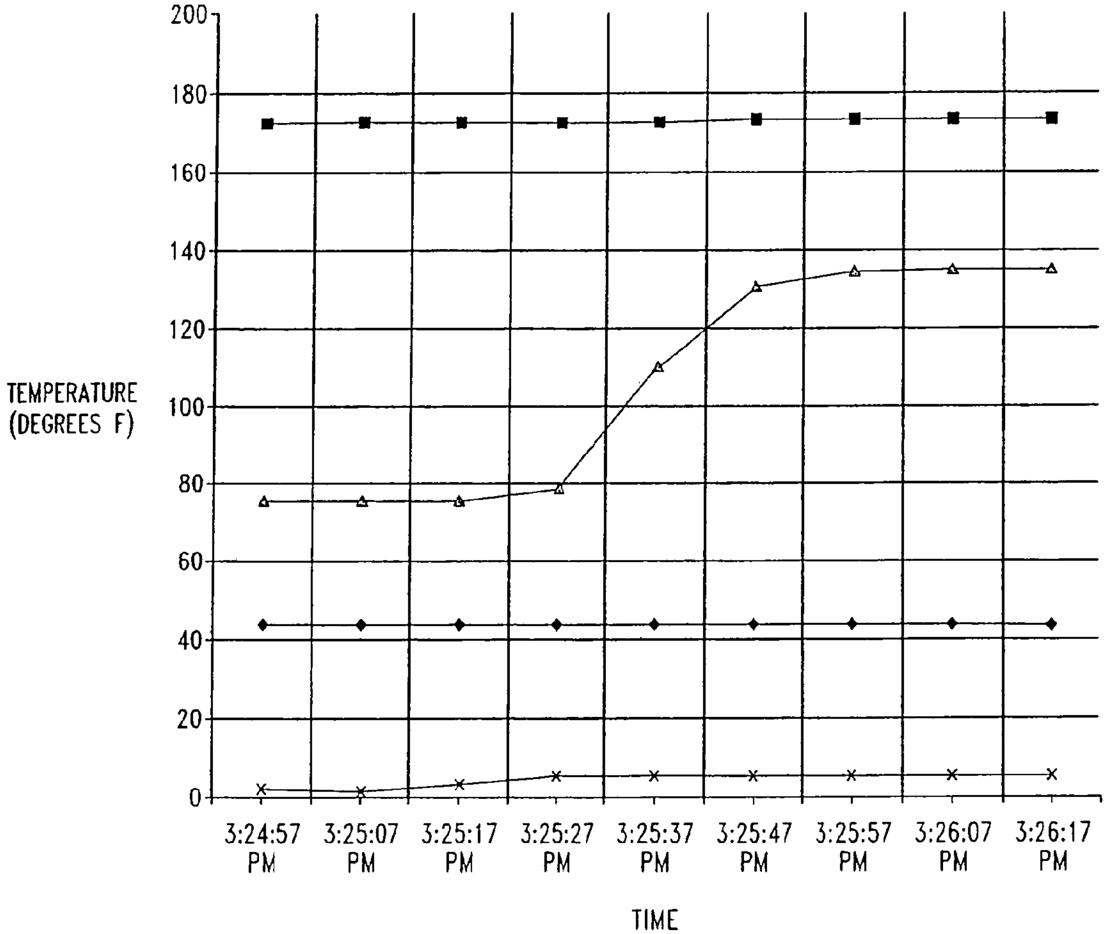
TIME

Fig. 19C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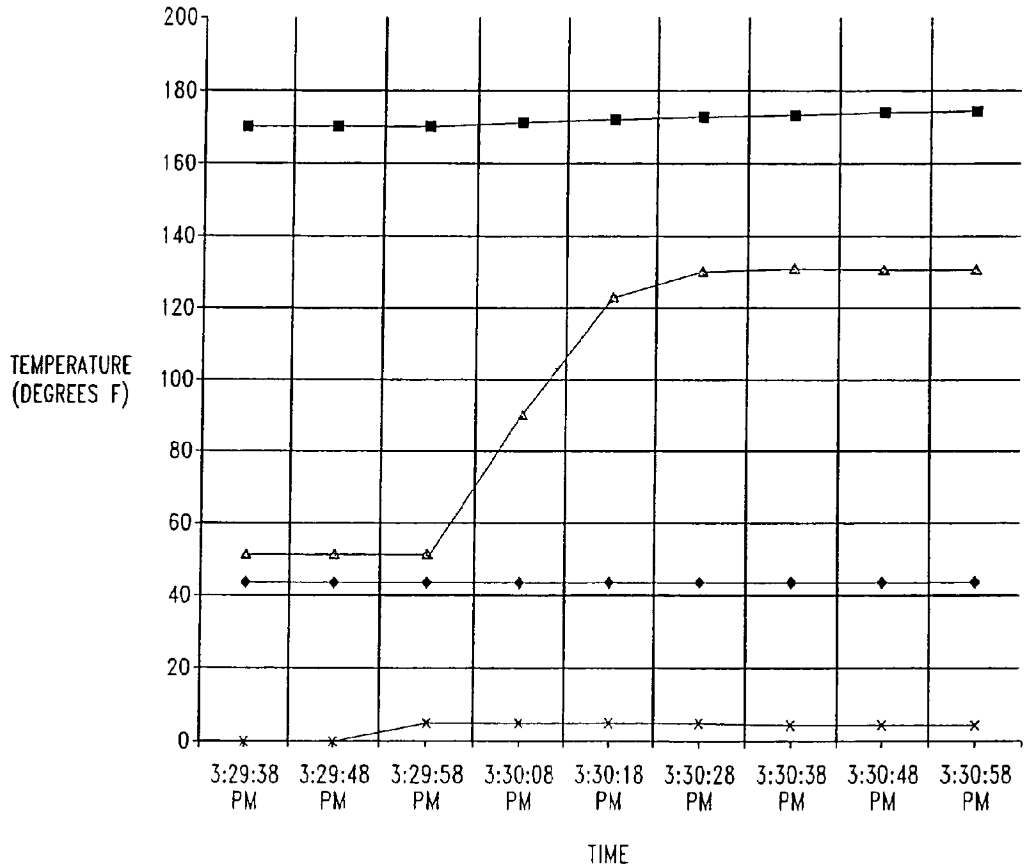
TIME

Fig. 19D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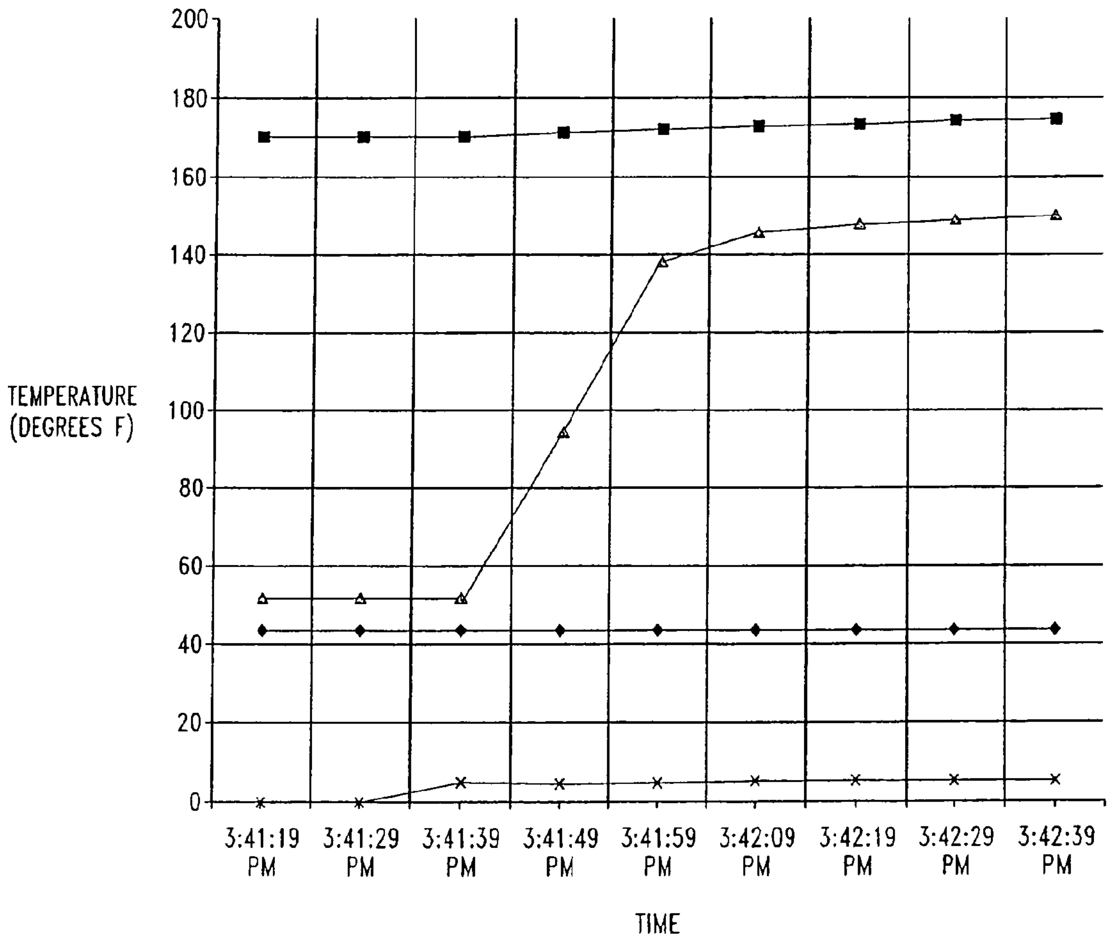
TIME

Fig. 19E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TIME

Fig. 19F

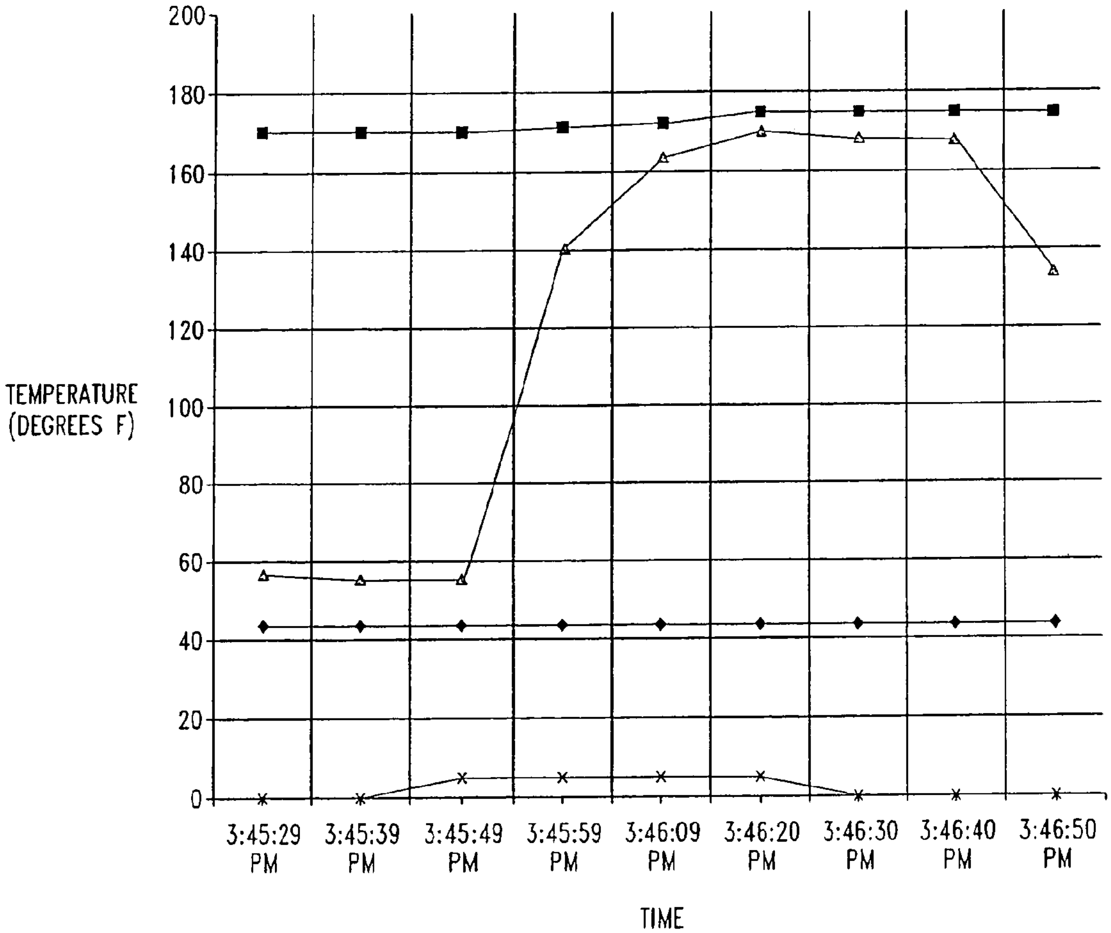
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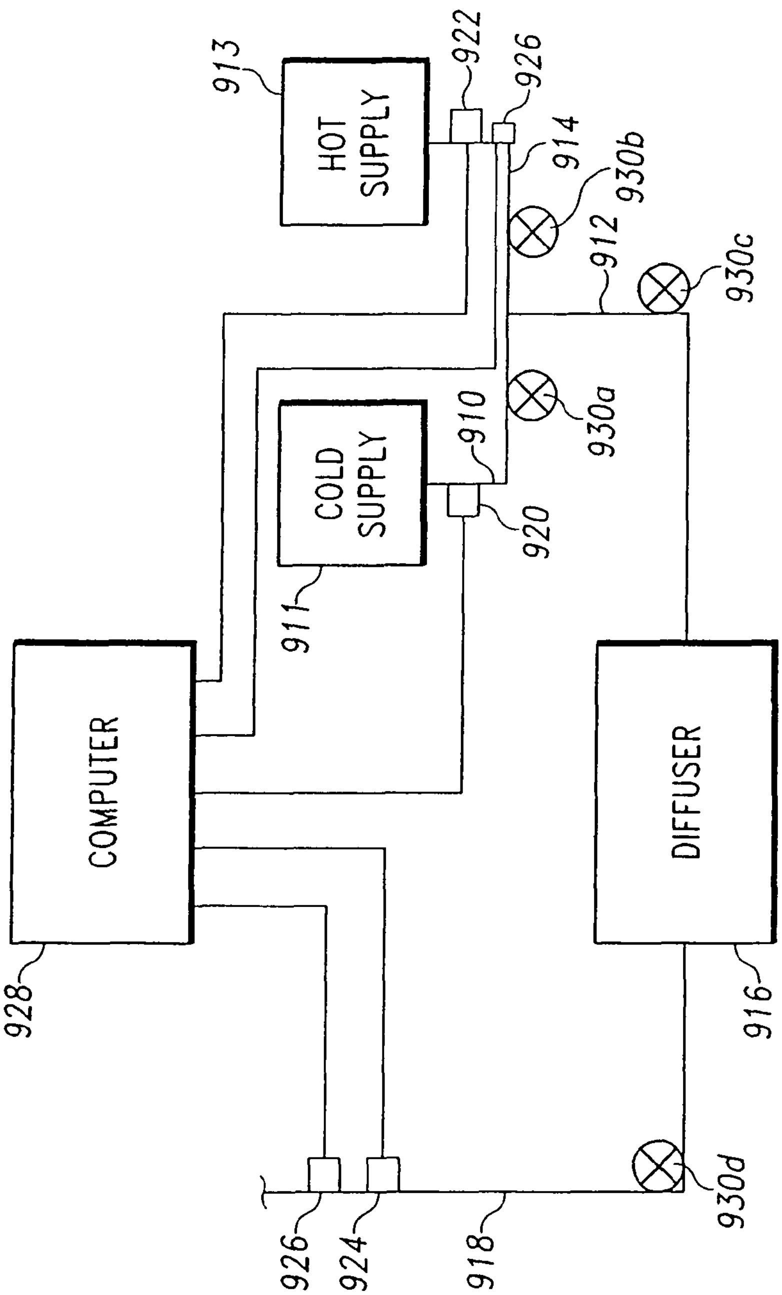
Fig. 19G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COLD SUPPLY
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COMPUTER
928
DIFFUSER
916
930d
926
924
918

Fig. 20

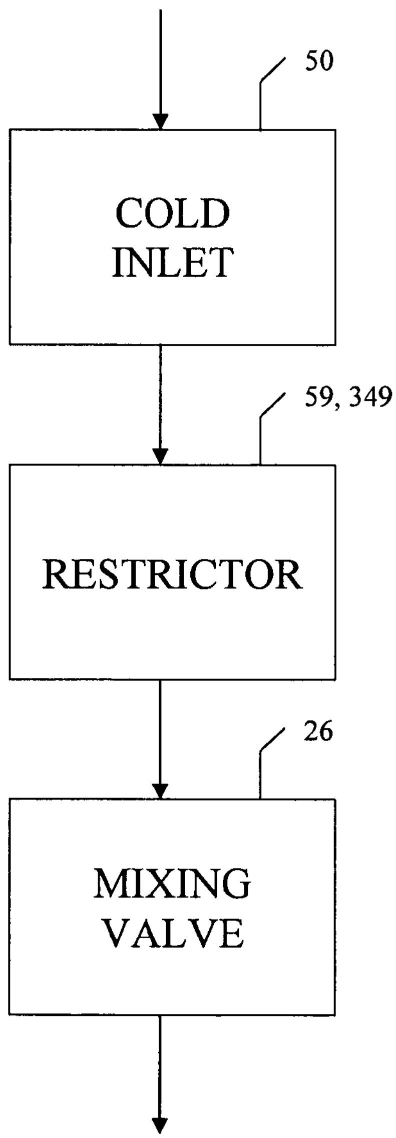
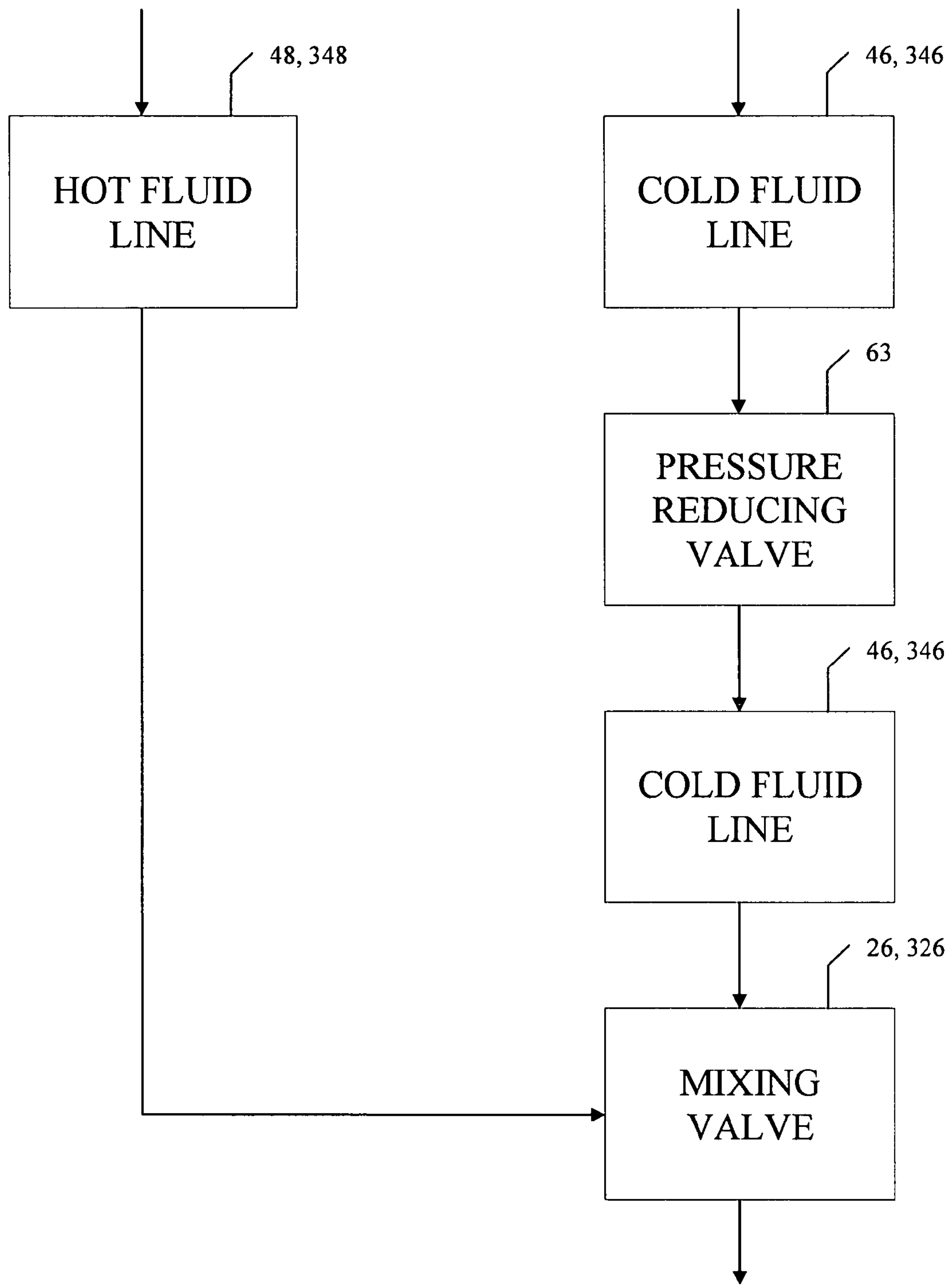


Fig. 21


48, 348
HOT FLUID LINE
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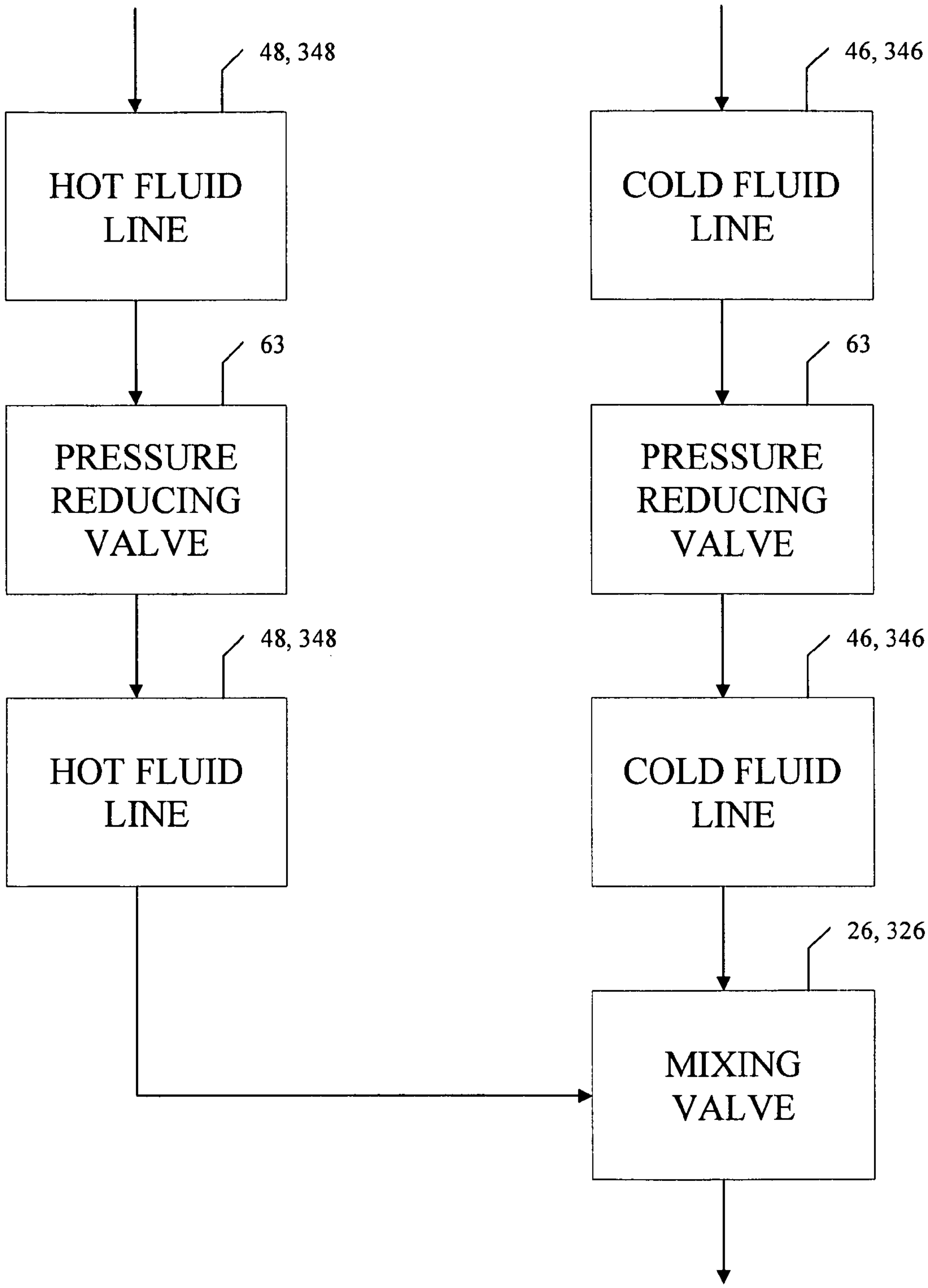
COLD FLUID LINE
63
PRESSURE REDUCING VALVE
46, 346
COLD FLUID LINE
26, 326
MIXING VALVE

Fig. 22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COLD FLUID LINE
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PRESSURE REDUCING VALVE
46, 346
COLD FLUID LINE
26, 326
MIXING VALVE

Fig. 23

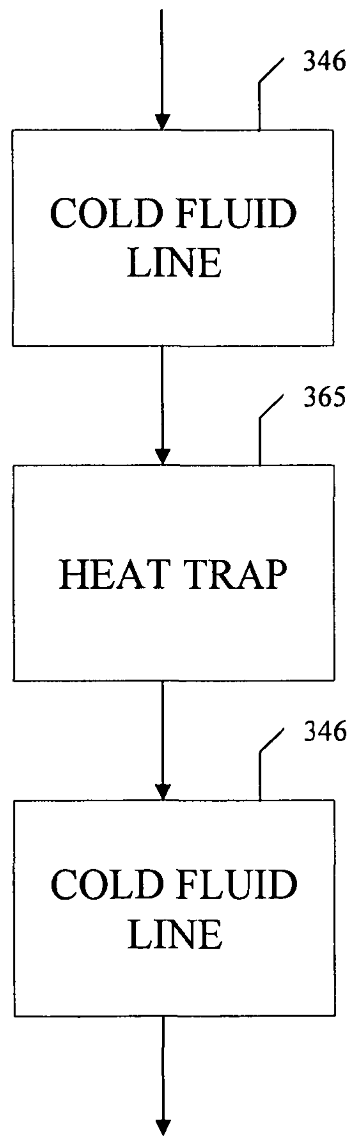
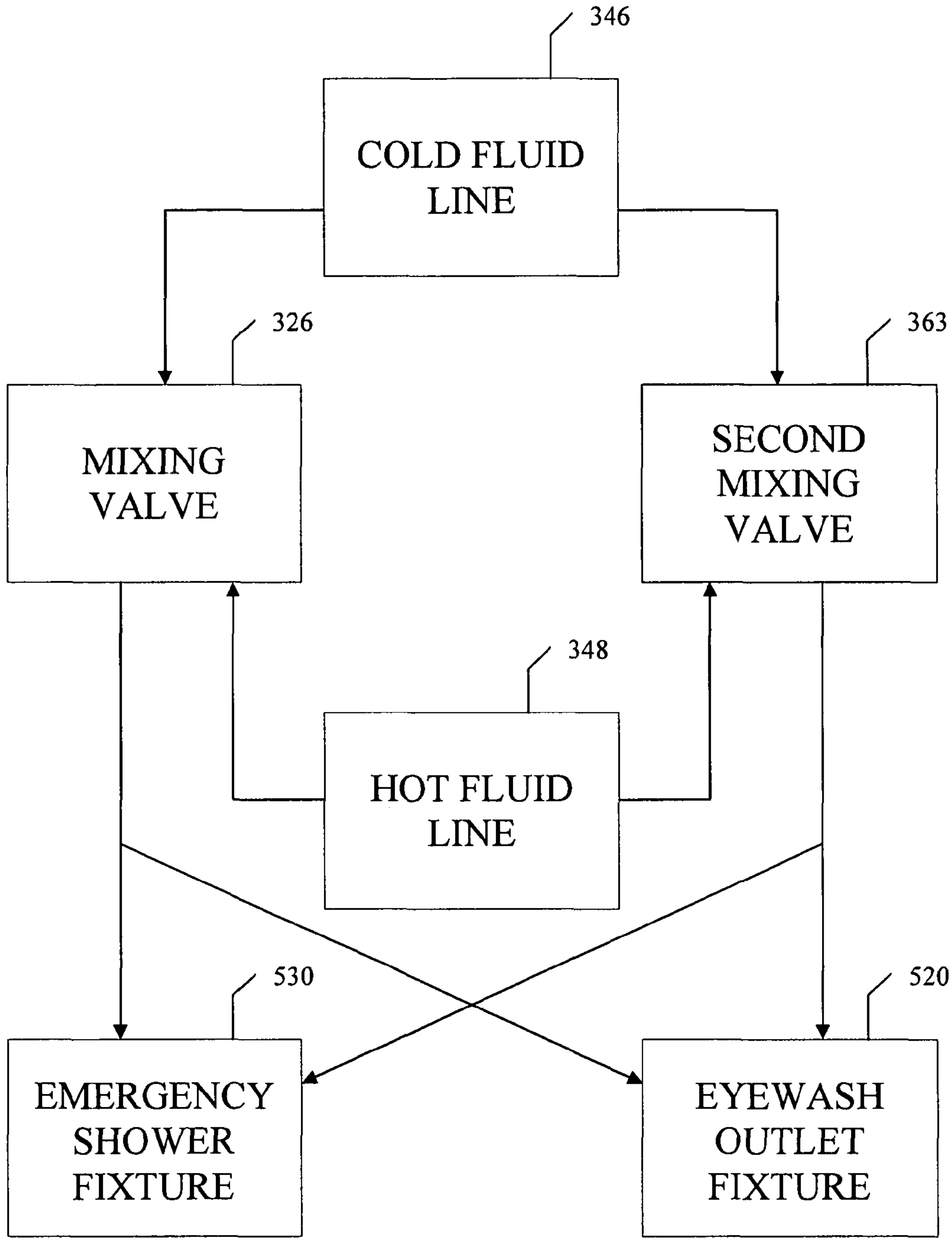


Fig. 24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COLD FLUID LINE
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MIXING VALVE
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SECOND MIXING VALVE
348
HOT FLUID LINE
530
EMERGENCY SHOWER FIXTURE
520
EYEWASH OUTLET FIXTURE

Fig. 25

SYSTEM AND METHOD FOR PROVIDING TEMPERED FLUID

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 11/493,164, filed Jul. 26, 2006, now issued as U.S. Pat. No. 8,209,796, which is a continuation-in-part of U.S. patent application Ser. No. 11/180,380, filed Jul. 13, 2005, now issued as U.S. Pat. No. 7,657,950, which is based on U.S. Provisional Application No. 60/592,710, filed Jul. 30, 2004, all of which are hereby incorporated by reference in is their entirety.

BACKGROUND AND SUMMARY OF THE INVENTION

The present invention concerns a method and apparatus for tempering the temperature of a liquid in a fluid conducting system. More particularly, the invention relates to tempering the temperature of water supplied to a fixture from a water heater in a fluid conducting system.

Thermally controlled or thermostatic mixing valves are well known. Valves of this type receive both hot and cold fluid, typically water, and allow the fluids to mix to an intermediate temperature. The temperature is controlled using a thermally responsive control member, such as a thermostat, to assist in maintaining the fluid temperature according to an established setting.

One particular application of thermostatic mixing valves is in connection with emergency shower and eyewash systems. Toxic and hazardous chemicals are used in many environments, whether inside a factory building or outside at a remote construction site. The Occupational Safety and Health Act of 1970 was enacted to assure that workers would be provided with safe and healthful working conditions. Pursuant to this act, the Occupational Safety and Health Administration adopted regulations which require the availability of emergency eyewash and shower equipment for use as a form of first aid treatment. Emergency shower and eyewash systems have proliferated in a wide range of industries, including automotive, food processing, chemical processing, petroleum refining, steel production, pulp and paper, and waste water treatment. In each of these industries, workers may be exposed to chemicals that may cause serious tissue damage and destruction. These emergency shower and eyewash facilities are commonly associated with permanent structures and may be located inside or outside factory buildings with access to hot and cold water.

In emergency fixture systems such as eyewash and emergency shower systems, even ground water of a moderate temperature (such as in the range of 50 degrees to 60 degrees F., as is common) is often perceived to be too cold, possibly discouraging sufficient duration of use of the emergency equipment. In addition, in northern climates, the ground water itself is sometimes barely above freezing, commonly near 35 degrees F. Under these circumstances, an emergency shower and eyewash system relying solely upon ground water often provides water that would be too cold to be endured for a sufficient period of time, even by a victim of a chemical accident.

As a result, emergency shower and eyewash systems have been designed to provide tempered water by blending relatively hotter water with relatively colder water. A range of temperatures between 65 degrees F. to 95 degrees F. is comfortable to most persons. To provide tempered water within this range, most emergency fixture systems include a source of hot water, typically in the range of 140 degrees F. to 160 degrees F., that is mixed with ambient ground water.

Many outdoor or other remote worksites such as construction sites may have the same or similar hazards that are associated with indoor worksites. Such remote worksites typically do not have a ready supply of hot water. Thus, workers at such sites exposed to chemicals or other irritants typically do not have access to emergency fixture systems that provide an adequate supply of tempered fluid, properly directed, for a sufficient period of time. Such workers may be required to resort to a ground-temperature water supply from a garden hose, a squirt bottle eye rinse apparatus, or other less suitable sources of fluid to rinse the exposed area(s).

Emergency shower and eyewash systems must typically drench or rinse a user for at least 15 minutes. Thus, the source of tempered water should be able to provide the water for at least that length of time and to maintain the water within a comfortable temperature range for the user. In addition, the system should be able to maintain tempering of the water regardless of extreme fluctuations in the supply of hot or cold water to the thermostatic mixing valve. Often, a thermostatic mixing valve is used to maintain the water at an appropriately tempered temperature.

The valve should respond accordingly to failures in the supply of hot or cold water to the valve, as well as failure of the valve itself. The valve should respond to these failures without placing the user of the emergency shower or eyewash system in greater peril than the user would be without the emergency system. For example, if the cold water supply fails and only hot water in the range of 140 degrees F. to 160 degrees F. is supplied, the user could suffer burns that may be more serious than the exposure being treated. Thus, it is desirable for the valve to prevent or minimize exposure to such hot water.

In addition, fluid flow through a mixing valve must not be compromised due to relative differences in fluid pressure from a cold fluid supply and a hot fluid supply. If the relative pressure of one fluid supply is significantly higher than another fluid supply, a mixing valve may "bypass" the fluid supply of relatively lower pressure, allowing only fluid from the relatively higher pressure fluid supply to flow through a mixing valve. If a cold fluid supply is bypassed by a mixing valve, depending on the type of mixing valve used, the flow of hot fluid would either be fully restricted or would be moderately or significantly restricted. If the cold fluid is bypassed and the mixing valve fully restricts the flow of hot fluid, no fluid would flow. However, if the cold fluid is bypassed and the mixing valve only either moderately or significantly reduced the flow of hot fluid, a user could suffer severe burns. Conversely, if only cold fluid is supplied through a mixing valve, bypassing the hot fluid, a user may not be properly decontaminated by using an emergency shower and/or eyewash due to the fluid being too uncomfortably cold to the user. Accordingly, it is desirable for a system to include means as necessary to restrict the pressure of fluid from one or more fluid supply sources as to prevent unintended and undesirable bypass of a mixing valve.

Additionally, the flow of mixed fluid from an emergency fixture system with relatively low fluid flow requirements, such as an emergency eyewash system, and from an emergency fixture system with relatively high fluid flow requirements, such as an emergency shower system, must flow at appropriate temperatures. Accordingly, it is desirable, as necessary, to provide a system including one or more mixing valves allowing mixed fluid to flow to emergency fixture systems with relatively low and relatively high fluid flow requirements.

Thermostatic mixing valves typically include a housing including hot and cold inlets, a mixed fluid outlet, a valve control assembly to adjust the amounts of hot and/or cold fluid permitted to flow through the valve, and a thermostat to control movement of the control assembly. The thermostat is typically positioned at least partially in the housing to sense the temperature of the mixture of fluid therein. The thermostat includes a material that is responsive to changes in the fluid temperature. For example, if the temperature increases, then movement of the thermostat causes movement of the control assembly, either increasing the flow of cold fluid, decreasing the flow of hot fluid, or both.

Frequently, some fluid in the fluid circulation system of which the thermostatic mixing valve is a part has been stagnant for a period of time. During this stagnancy, the temperature of the hot fluid in the hot fluid supply line approaches ambient temperature, usually lower than the temperature of the hot fluid from the hot fluid supply. In a typical thermostatic mixing valve, when the temperature of the mixed fluid sensed by the thermostat is below the set point, the thermostat cooperates with the valve control assembly to increase the flow of hot fluid relative to the flow of cold fluid.

In such a stagnant fluid circulation system, when a fixture (such as an eyewash station) is eventually actuated, the thermostat is often exposed to mixed water at a temperature below the set point temperature, even if the ratio of water from the hot and cold fluid supplies otherwise would be proportioned (if the hot fluid were at temperature) to produce mixed fluid at the desired temperature. Accordingly, responsive changes in the thermostat cause the valve control assembly to move to a position that increases the flow of hot fluid relative to the flow of cold fluid, thus increasing the mixed fluid temperature. As the valve continues to receive the supply of fluid from the hot fluid supply line that was formerly stagnant, the thermostat continues to cause the valve control assembly to move to a position that further increases flow from the hot fluid supply line and/or decreases the flow of cold fluid. If a sufficient volume of stagnant fluid is in the supply line between the hot fluid supply and the mixing valve, this process may continue until the thermostat has caused the valve assembly to move to a position wide-open to maximize the flow of fluid from the hot fluid source.

Eventually, hot fluid from in the hot fluid supply (such as a water heater) progresses to the mixing valve. Because the valve control assembly is now wide-open to the hot fluid inlet, a large volume of hot fluid enters the valve housing through the hot fluid supply line that had previously been the source of the stagnant (and cooler) fluid. Once the hot fluid reaches the thermostat after mixing with whatever cold fluid is entering the valve, the thermostat responds to the temperature increase, causing the valve control assembly to move to reduce the flow of hot fluid and/or increase the flow of cold fluid. The length of time for the thermostat to respond as such and move the valve control assembly by a sufficient amount to reduce the temperature of mixed fluid below the set point can be long enough to permit a quantity of water above the set point temperature to flow from the valve.

Thus, in one aspect of the invention, a decontamination apparatus is provided, comprising a fluid supply inlet configured for coupling to a fluid supply source, a first fluid line coupled to the fluid supply inlet and formed to include a first passageway in which a first fluid flows, and a heat exchange assembly configured to heat the first fluid in the first fluid line. The apparatus also comprises a mixing valve including a valve body formed to include a first fluid inlet to receive the first fluid from the first fluid line, a second fluid inlet to receive a second fluid from a second fluid line, and a mixed fluid outlet. A decontamination fixture is coupled to the mixed fluid outlet configured to discharge the mixed fluid. Optionally, a support interconnects at least the heat exchange assembly, the first fluid line, the mixing valve, and the decontamination fixture to permit movement of the apparatus as a unit.

In an additional aspect of the invention, a restrictor may be positioned between a first fluid inlet and a mixing valve. In another aspect of the invention, one or more pressure reducing valves may be positioned within a first fluid line and/or a second fluid line prior to a mixing valve.

In yet another aspect of the invention, a first fluid from a first fluid line and a second fluid from a second fluid line may flow to a mixing valve and/or to a second mixing valve, allowing fluid to mix in a second mixing valve when fluid flow out of a decontamination apparatus is relatively low and allowing fluid to mix in a mixing valve and a second mixing valve when fluid flow out of a decontamination apparatus is relatively high. It is understood in this aspect of the invention that a first fluid from a first fluid line and a second fluid from a second fluid line may mix in one or both mixing valves under all conditions of fluid flow out of a decontamination apparatus.

In one illustrative example according to this aspect of the invention, the support is a frame including frame members coupled together, a platform coupled to the frame, and wheels coupled to the frame to facilitate movement of the decontamination apparatus.

In another illustrative example according to this aspect of the invention, the support includes a platform having a structure including a generally upwardly facing surface on which the heat exchange assembly, mixing valve, and decontamination fixture are supported, and a plurality of spaced apart support members coupled to and extending downwardly from the structure.

Illustratively according to this aspect of the invention, the first and second fluid lines comprise fluid provided by the fluid supply source.

Additionally illustratively according to this aspect of the invention the apparatus further comprises a junction in fluid communication with the fluid supply inlet, the junction splitting flow of fluid from the fluid supply source into the first fluid line and the second fluid line.

Illustratively according to this aspect of the invention the second fluid line configured to be coupled to a second fluid supply source and formed to include a second passageway in which a second fluid stream flows.

Illustratively according to this aspect of the invention the heat exchange assembly comprises a burner configured to combust fuel from a fuel source, and at least a portion of the first fluid passageway is proximate the burner so that when fuel from the fuel source is combusted at the burner, heat from the combustion is transferred into the first fluid in the first fluid passageway.

Additionally illustratively according to this aspect of the invention, the burner is coupled to a controller, the decontamination fixture includes an actuator to actuate a valve controlling flow of fluid from the decontamination fixture, the burner igniting upon actuation of the decontamination fixture by a signal sent by the controller.

Additionally illustratively according to this aspect of the invention the apparatus further comprises a fuel tank in which the fuel is stored, the fuel tank coupled to the frame to enable movement of the fuel tank upon movement of the frame.

Illustratively according to this aspect of the invention the apparatus further comprises wheels coupled to the frame to facilitate movement of the decontamination apparatus.

Additionally illustratively according to this aspect of the invention the apparatus further comprises a stand coupled to the frame to cooperate with the wheels to maintain decontamination apparatus in a position suitable for use by a user.

Illustratively according to this aspect of the invention, the apparatus further comprises a means for dampening temperature change of the first fluid prior to entry into the first fluid inlet of the thermostatic mixing valve so that the mixing valve can adjust to a particular temperature increase over a given time period.

Illustratively according to this aspect of the invention, the apparatus further comprises a diffuser coupled between the hot fluid line and the hot inlet to the mixing valve, the diffuser including a first fluid conduit and at least a second fluid conduit, a majority of the first fluid conduit being surrounded by the second fluid conduit, the first and second conduits being coupled together to cause fluid to flow into the first conduit, pass through a plurality of apertures formed in the first conduit, and into fluid outside the first conduit and in the second conduit.

Illustratively according to this aspect of the invention, the decontamination fixture is an eyewash fixture including a basin and at least one nozzle directed at least partially upwardly.

Illustratively according to this aspect of the invention, the decontamination fixture is a drench shower having fluid outlets directed at least partially downwardly.

Illustratively according to this aspect of the invention, the decontamination fixture is a wand including a trigger configured to be actuated by a user and a spray nozzle to direct the flow of fluid from the wand depending on a direction selected by a user.

According to another aspect of the invention, an apparatus for increasing the time period over which a temperature change occurs at a point in a fluid conducting system having fluid flowing therethrough comprises a first conduit having first and second ends and a plurality of openings provided between the first and second ends, a second conduit having first and second ends, the second conduit being coupled to the first conduit and at least partially surrounding at least a portion of the first conduit, wherein at least one of the openings is in the portion of the first conduit surrounded by the second conduit, one of the second conduit and the first conduit including a fluid inlet, and the other of the second conduit and the first conduit including a fluid outlet, wherein the first and second conduits are arranged to permit fluid to flow from the inlet to the outlet.

Illustratively according to this aspect of the invention, the second conduit and the first conduit are connected together to permit fluid to flow from the fluid inlet toward the fluid outlet.

Additionally illustratively according to this aspect of the invention, the first conduit and the second conduit are coupled together by a union that seals a first end of each of the first and second conduit so that fluid is inhibited from passing from the first end of the first conduit into the region between the first and second conduits adjacent the first end of the first conduit.

Further illustratively according to this aspect of the invention, a second end of the second conduit is sealed with a cap to prevent fluid from flowing out of the second end of the second conduit.

Further illustratively according to this aspect of the invention, a second end of the first conduit is spaced apart from the cap to permit fluid to flow from the second end of the first conduit adjacent the cap, and into the region between the first and second conduits.

Additionally illustratively according to this aspect of the invention, the union is formed to include an outlet to permit fluid to flow from the first end of the second conduit out of the outlet.

Further illustratively according to this aspect of the invention, the union includes a first end having an opening sized to receive the first end of the second conduit, and the union includes a second end having an opening sized to receive the first end of the first conduit.

Further illustratively according to this aspect of the invention, the first and second ends of the union are separated by a generally frustoconical reducing region.

Illustratively according to this aspect of the invention, the first and second fluid conduits are coupled so that fluid flowing within the first conduit flows substantially in the opposite direction as fluid flowing within the second conduit.

Additionally illustratively according to this aspect of the invention, the apparatus further comprises a third fluid conduit, wherein at least a portion of the first fluid conduit is surrounded by the second and third fluid conduits, and at least a portion of the second fluid conduit is surrounded by the third fluid conduit.

Further illustratively according to this aspect of the invention, the fluid flowing through and immediately adjacent to the first and third fluid conduits flows in a direction substantially parallel within each conduit.

Illustratively according to this aspect of the invention, the apparatus further comprises a plurality of apertures in the second fluid conduit comprise a first aperture, a second aperture, and a third aperture, the first aperture being spaced from the second aperture by a first distance, and the second aperture being spaced from the third aperture a second distance, the first distance being greater than the second.

Illustratively according to this aspect of the invention, the first and second fluid conduits define a void having a volume capable of receiving at least 0.13 gallons of fluid.

Additionally illustratively according to this aspect of the invention, the first, second and third conduits define a void having a volume capable of receiving at least 0.9 gallons of fluid.

Illustratively according to this aspect of the invention, the plurality of each of the apertures is substantially of one of the shapes selected from the group consisting of: circular, square, rectangular, diamond-shaped, ovular, triangular, and irregular.

According to another aspect of the invention, a fluid mixing apparatus for use in a fluid flow network comprises a mixing valve including a housing having a hot fluid inlet, a cold fluid inlet, a mixed fluid outlet, a mixing region, and a movable valve assembly to adjust the relative flow of fluid through the hot fluid inlet and the cold fluid inlet, and a first fluid conduit in fluid communication with the mixing valve, the first fluid conduit including an inlet through which fluid flows from a hot fluid supply line and an outlet through which fluid flows toward the mixing valve, the first fluid conduit constructed to expose fluid flowing through the inlet to a heat sink.

Illustratively according to this aspect of the invention, the heat sink is a second fluid mass downstream of a first fluid mass. Additionally illustratively according to this aspect of the invention, the apparatus further comprises a second fluid conduit coupled to the first fluid conduit, the first fluid conduit formed to include the inlet and formed to include a first conduit outlet through which fluid is capable of flowing out of the first fluid conduit and into the second fluid conduit. Further illustratively according to this aspect of the invention, the apparatus further comprises a third conduit between the first and second fluid conduits. Additionally illustratively according to this aspect of the invention, the first fluid conduit has a length, and is formed to include a plurality of openings, at least one of the plurality of openings positioned between the ends of the first fluid conduit. Additionally illustratively according to this aspect of the invention, a portion of the first fluid conduit is surrounded by the second fluid conduit. Additionally illustratively according to this aspect of the invention, at least one of the first and second fluid conduits includes a plurality of fins extending from a surface of said one of the first and second fluid conduits. Further illustratively according to this aspect of the invention, said one of the first and second fluid conduits is formed to include a plurality of apertures, at least one of said plurality of apertures positioned between the ends of the fluid conduit including fins.

Illustratively according to this aspect of the invention, the heat sink is a thermally conductive material having a mass per unit of linear length of net fluid flow greater than the average mass per unit of linear length of net fluid flow in the fluid flow network. Additionally illustratively according to this aspect of the invention, the heat sink comprises copper.

Illustratively according to this aspect of the invention, the heat sink surrounds the first conduit so that fluid flowing from the first fluid conduit subsequently flows through a passageway defined by the heat sink.

According to another aspect of the invention a decontamination apparatus comprising a fluid heater, a cold fluid supply line, a hot fluid supply line for supplying hot fluid from the fluid heater to a thermostatic mixing valve, the thermostatic mixing valve having a hot fluid inlet for receiving fluid from to the hot fluid supply line, a cold fluid inlet for receiving fluid from the cold fluid supply line, and a mixed fluid outlet for supplying fluid to a mixed fluid supply line through which one, the other, or both of the hot and cold fluids flow from the thermostatic mixing valve, an emergency fixture connected to the mixed fluid supply line for supplying fluid therefrom to a user and configured to deliver the mixed fluid at a flow rate and pattern to decontaminate effectively at least a portion of the user's body, and a diffuser coupled between the hot fluid supply line and the thermostatic mixing valve for increasing the time over which a temperature change is observed at the hot fluid inlet.

In another aspect of the invention a decontamination apparatus comprises a fluid supply inlet configured for coupling to a fluid supply source, a circulation network coupled to the fluid supply inlet and formed to include a first passageway in which a first fluid flows, a heater to heat the first fluid stream in the circulation network, a decontamination fixture connected to the circulation network to receive heated fluid from the heater, and a support interconnecting at least the heater, fluid circulation network, and the decontamination fixture to permit movement of the apparatus as a unit.

Illustratively according to this aspect of the invention, the apparatus further comprises a mixing valve comprising a valve body formed to include a first fluid inlet to receive a first fluid from a first fluid line, a second fluid inlet to receive a second fluid from a second fluid line, and a mixed fluid outlet. Additionally illustratively according to this aspect of the invention, the mixing valve further includes a valve assembly operably coupled to a thermostat to move the valve assembly to adjust the flow of at least one of the first and the second fluids to control the mixed fluid temperature.

Additionally illustratively according to this aspect of the invention, the support is a pallet into which the tines of a fork truck can be inserted to lift and move the apparatus as a unit. Additionally illustratively according to this aspect of the invention, the support is a frame having wheels coupled thereto so that a user can move the apparatus as a unit. Additionally illustratively according to this aspect of the invention, the decontamination fixture includes a valve operated by an actuator, and operation of the actuator causes fluid to flow from the circulation network through the mixing valve and through the decontamination fixture. Further illustratively according to this aspect of the invention, operation of the actuator causes the heater to ignite and heat the fluid flowing through the circulation network.

Additionally illustratively according to this aspect of the invention, the apparatus further comprises a diffuser positioned in the circulation network to receive fluid from the heater, the diffuser configured to increase the time over which a temperature increase is observed at the inlet of the fluid from the heater to the mixing valve.

Illustratively according to this aspect of the invention, the apparatus further comprises a fuel tank to store fuel usable by the heater to generate heat for heating the fluid in the circulation network. Additionally illustratively according to this aspect of the invention, the support is a frame having wheels coupled thereto so that a user can move the apparatus as a unit.

Additionally illustratively according to this aspect of the invention, the heater is configured to heat fluid on demand as the fluid flows through the circulation network.

Illustratively according to this aspect of the invention, the heater includes a storage tank and is configured to heat fluid and store the heated fluid in the storage tank.

Additional features of the invention will become apparent to those skilled in the art upon consideration of the following detailed description of a preferred embodiment exemplifying the best mode of carrying out the invention as presently perceived.

BRIEF DESCRIPTION OF THE DRAWINGS

The detailed description particularly refers to the accompanying figures in which:

FIG. **1** illustrates a decontamination apparatus for tempering fluid to rinse substances from body parts of a victim, the apparatus having a heat exchange unit, fuel source, decontamination fixture, fluid circulation network, diffuser, and mixing valve coupled with a support to facilitate transportation of the decontamination apparatus;

FIG. **2** illustrates internal components of an illustrative heater for use with the decontamination apparatus of FIG. **1**;

FIG. **3** illustrates a decontamination apparatus for tempering fluid including a heat exchange unit, fluid circulation network, decontamination fixture, diffuser, and mixing valve positioned on a support platform to facilitate transportation of the decontamination apparatus;

FIG. **4** is a cross-sectional view of the diffuser shown in FIG. **1**, taken along line **4-4** thereof, showing the first and second conduits cooperating to form a two-pass diffuser;

FIG. **5** is a cross-sectional view of the diffuser shown in FIG. **3**, taken along line **5-5** thereof, showing the first, second, and third conduits cooperating to form a two-pass diffuser;

FIG. **6** is a perspective view of a decontamination fixture including a drench shower and an eyewash station;

FIG. **7** is a perspective view of a conduit for a diffuser having a spiral fin projecting away from the centerline through the conduit;

FIG. **8** is a cross-sectional view of a conduit for a diffuser having a plurality of holes formed therein;

FIG. **9** is a cross-sectional view of a conduit for a diffuser similar to FIG. **8** showing a hole having a diamond shape;

FIG. **10** is a cross-sectional view of a conduit for a diffuser similar to FIG. **8** showing a hole having an oval shape;

FIG. **11** is a cross-sectional view of a conduit for a diffuser similar to FIG. **8** showing a slot having a elongated rectangular shape;

FIG. **12** is a cross-sectional view of a conduit for a diffuser similar to FIG. **8** showing a hole having a trapezoidal shape;

FIG. **13** is a cross-sectional view of a conduit for a diffuser similar to FIG. **8** showing a plurality of circular holes spaced apart by varying distances;

FIG. **14** is a fragmentary view of a portion of the heater of FIG. **2**, showing a pilot assembly with an igniter and a flame sensor;

FIG. **15** is a view of the pilot assembly of FIG. **14** showing a pilot flame;

FIG. **16** is a diagrammatic view of the heater of FIG. **2**, showing a computer connected to a gas proportioning valve, to a flow sensor that is also coupled to the fluid inlet to the heater, and to a thermistor that is also coupled to the hot fluid outlet line, the heat exchanger and a fuel inlet line;

FIG. **17** is a schematic view of the heater of FIG. **2** showing safety circuitry including an overheat sensor, temperature limiter, and flue gas safety sensors and switches arranged in series and coupled to a valve to shut off flow of fuel upon detection of certain conditions;

FIG. **18** is a diagrammatic view of a decontamination apparatus including a fluid supply, a heat exchanger receiving fluid from the fluid supply and feeding heated fluid to a diffuser, the diffuser feeding fluid to a mixing valve that, optionally, receives a supply of cold fluid from a cold fluid source, and a mixed fluid stream flowing from the mixing valve to an optional second diffuser then to an application;

FIGS. **19**A through **19**G are graphical data, also shown in tabular form in Table 1, of a test performed with a circulation system including hot and cold inlets, a diffuser similar to the diffuser of FIG. **5**, and a mixed fluid outlet coupled to the diffuser, wherein -.diamond-solid.- represents cold water, -.box-solid.- represents hot water, -.tangle-solidup.- represents mixed water temperature, and -x- represents water pressure;

FIG. **20** is a diagrammatic view of a test apparatus showing a cold fluid supply, a hot fluid supply, a mixed fluid outlet, a diffuser coupled between the supplies and the mixed fluid outlet, and decontamination apparatus including a plurality of sensors coupled to the test apparatus to provide data;

FIG. **21** is a diagrammatic view of a portion of a decontamination apparatus showing the location of a restrictor positioned between a mixing valve and a cold inlet;

FIG. **22** is a diagrammatic view of a portion of a decontamination apparatus showing the location of a pressure reducing valve positioned within a cold fluid line prior to a mixing valve;

FIG. **23** is a diagrammatic view of a portion of a decontamination apparatus showing the location of a pressure reducing valve positioned within a cold fluid line prior to a mixing valve and the location of a pressure reducing valve positioned within a hot fluid line prior to a mixing valve;

FIG. **24** is a diagrammatic view of a portion of a decontamination apparatus showing the location of a heat trap positioned within a cold fluid line; and

FIG. **25** is a diagrammatic view of aspects of an embodiment of a decontamination apparatus showing the location of a mixing valve and a second mixing valve positioned within a circulation network.

DESCRIPTION

As illustrated in FIG. **1**, a decontamination apparatus **20** includes a heat exchange assembly **22**, a fluid circulation network **24**, and a mixing valve **26**. In the embodiment of FIG. **1**, the heat exchange assembly includes a heater **28** for supplying heat to a fluid for increasing the temperature of the fluid. To facilitate transportation of decontamination apparatus **20**, a support **32** is illustratively provided and is connected to fluid circulation network **24** and heat exchange assembly **22**. A plurality of wheels **34** and a stand **36** are coupled to frame **32**. Wheels **34** and stand **36** cooperate with support **32**, illustratively a frame **33**, to support fluid circulation network **24** and heat exchange assembly **22** in the position depicted in FIG. **1**.

Circulation network **24** includes fluid supply inlet **40** to which a fluid supply line **42** is couplable, fluid supply line **42** illustratively shown as a hose in FIG. **1**. Fluid supply inlet **40** leads to a tee or other junction **44** at which fluid flowing through circulation network **24** is divided—a portion of the fluid flows into a cold fluid line **46** and a portion flows into hot fluid line **48**. Cold fluid line **46** extends from junction **44** to mixing valve **26**, and is coupled to cold inlet **50** of mixing valve **26**. Hot fluid line **48** extends from junction **44**, to heater **28**, and is coupled to mixing valve **26**. As fluid flows through hot fluid line **48** adjacent heater **28**, heat generated by heater **28** is applied to hot fluid line **48**, increasing the temperature of the fluid flowing therein. Hot fluid line **48** is coupled to hot inlet **52** of mixing valve **26**. Although FIG. **1** discloses junction **44** as dividing a single supply line into the hot and cold fluid streams, it is within the scope of this disclosure to have separate hot and cold fluid supply lines supplying respective hot and cold fluids.

As illustrated in FIG. **1**, mixing valve **26** includes a housing **54** in which are mixed hot fluid flowing through hot inlet **52** and cold fluid flowing through cold inlet **50**. Illustratively, mixed fluid temperature is controlled using a suitable thermostat and valve assembly, as is known in the art. While reference is made to thermostatic mixing valves, it is within the scope of this disclosure to use other types of mixing valves or systems as are known in the art, illustratively proportional mixing techniques, pressure balancing valves, pressure reducing valves, and the like. Mixed fluid flows from housing **54** through mixed fluid outlet **56**, and into mixed fluid line **58**. Mixed fluid line **58** leads to an emergency fixture depicted illustratively in FIG. **1** as an eyewash fixture **37**.

A restrictor **59** (internal location as shown in FIGS. **1** and **21**) may be positioned between cold inlet **50** and mixing valve **26**. The arrows in FIG. **21** represent the direction of fluid flow. Restrictor **59** may also define one or more holes. In one embodiment, restrictor **59** may be comprised of copper, be circular in shape, 1¼" in diameter, $^{10}/_{1000}$" ($^{1}/_{100}$") thick, and define a hole $^{3}/_{16}$" in diameter. Restrictor **59** may be comprised of metal, plastic, glass, or other suitable materials, may be sized and shaped with diameters and thicknesses suitable for the particular application, and may define one or more holes of varying diameters. Restrictor **59** operates to equalize differentials in pressure between cold fluid line **46** and hot fluid line **48** from heater **28** to mixing valve **26**. Restrictor **59** is therefore beneficial by equalizing pressures of cold fluid line **46** and hot fluid line **48** entering mixing valve **26** to stop mixing valve **26** from going into bypass, allowing only cold fluid from cold fluid line **46** to flow through mixing valve **26**. Bypass occurs in a thermostatic mixing valve when the pressure of the fluids in a fluid line or lines entering a mixing valve are either zero or so insufficient as not to be recognized by the mixing valve. Instead of the mixing valve preventing all fluid from flowing in or out, the mixing valve would bypass the fluid line or lines of zero or little pressure, allowing the fluid from the fluid lines with sufficient pressure to pass through the mixing valve. Conversely, if the relative pressure of one of the fluids is so high compared to the other fluids entering the mixing valve, the mixing valve may bypass the fluids of lesser pressure, allowing only the highest pressure fluid to pass through the mixing valve. Comparable operation of this “bypass” is possible with other types of mixing valves, as is well known in the art. Accordingly, if fluid pressure is zero or too low from hot fluid line **48**, mixing valve **26** may revert to bypass blocking off hot fluid from hot fluid line **48**, allowing only cold fluid from cold fluid line **46** to flow through mixing valve **26**. If fluid pressure is zero or too low from cold fluid line **46**, mixing valve **26** may revert to bypass blocking off the flow of cold fluid from cold fluid line **46** and, depending on the type of mixing valve, hot fluid from hot fluid line **48** would either be fully restricted or would be moderately or significantly restricted. If cold fluid from cold fluid line **46** is bypassed and mixing valve **26** fully restricts the flow of hot fluid from hot fluid line **48**, no fluid would flow. However, if cold fluid from cold fluid line **46** is bypassed and mixing valve **26** only either only moderately or significantly reduced the flow of hot fluid from hot fluid line **48**, a user could suffer severe burns. Additionally, if fluid pressure is too high from cold fluid line **46**, mixing valve **26** may only sense cold fluid and may revert to bypass blocking off the hot fluid from hot fluid line **48**. Restrictor **59**, when positioned between cold inlet **50** and mixing valve **26**, would act in this latter fashion to prevent bypass by decreasing the pressure of the cold fluid from cold fluid line **46**. It is within the scope of this embodiment that a restrictor **59** may also be positioned between hot inlet **52** and mixing valve **26**, with or without a restrictor **59** being positioned between hot inlet **50** and mixing valve **26**.

While reference is made to restrictor **59**, it is within the scope of this disclosure to use other means or systems as are known in the art to reduce the pressure of fluid flow through a conduit, such as pressure reducing valves and the like. For example, as shown in FIG. **22**, pressure reducing valve **63** may be positioned within cold fluid line **46** prior to mixing valve **26**. The arrows in FIG. **22** represent the directions of fluid flow. Pressure reducing valve **63** may operate to equalize differentials in pressure between cold fluid from cold fluid line **46** and hot fluid from hot fluid line **48** to mixing valve **26** by restricting the pressure of cold fluid from cold fluid line **46**. A suitable pressure reducing valve **63** is available in the form of a model number 600 from Wilkins Industries, a Zurn Company, Erie, Pa., USA, although other pressure reducing valves are suitable, as are known in the art.

An additional embodiment, as shown in FIG. **23**, demonstrates an embodiment utilizing multiple pressure reducing valves. In this embodiment, pressure reducing valves **63** may be positioned within cold fluid line **46** prior to mixing valve **26** and may also be positioned within hot fluid line **48** prior to mixing valve **26**. The arrows in FIG. **23** represent the directions of fluid flow. Pressure reducing valves **63** may operate to equalize differentials in pressure between cold fluid from cold fluid line **46** and hot fluid from hot fluid line **48** to mixing valve **26** by restricting the pressure of cold fluid from cold fluid line **46** and the pressure of hot fluid from hot fluid line **48**. It is within the scope of this embodiment that one or more pressure reducing valves **63** may be positioned either directly adjacent to mixing valve **26** or prior to an inlet of mixing valve within cold fluid line **46** and/or cold fluid line **48**.

As illustrated in FIG. **1**, circulation network **24** has positioned therein a first diffuser **30** between the portion of hot fluid line **48** adjacent heater **28** and hot inlet **52** of mixing valve **26**. Illustratively, circulation network **24** has positioned therein a second diffuser **30**A between mixed fluid outlet **56** from mixing valve **26** and eyewash fluid inlet line **38**. Eyewash fluid inlet line **38** includes a valve **39** therein that is operable by actuation of actuator **41**. When a user actuates actuator **41**, opening valve **39**, mixed fluid flows from mixed fluid outlet **56** through mixed fluid line **58**, toward eyewash fixture **37**, through eyewash fluid line **38**, and out eyewash outlets **43** of eyewash fixture **37**. Refuse fluid is captured, at least in part, by basin **45** and is permitted to exit by way of drain **47**. Illustratively, when a user actuates actuator **41**, a burner or other heating element (described more fully below) is ignited or otherwise powered to heat fluid flowing through hot fluid line **48**. Optionally, decontamination apparatus **20** can be provided as a mobile unit.

As illustrated in FIG. **1**, frame **33** includes side members **35** that are coupled to heater **28**. Side members **35** are coupled to a base **49** illustratively including an axle tube **51** coupled to lower ends of side members **35** and an axle (not shown) extending therethrough. Wheels **34** are coupled to the axle to facilitate transport of decontamination apparatus **20**. Base **49** of frame **33** further includes a platform **53** having a generally upwardly facing surface **55**. Handles **57** are coupled to side frame members **35** to further facilitate transport. Upper frame section **59** is connected to side members **35**, and illustratively is a generally rectangular tubular section that extends outwardly from side members **35** to provide additional support for heater **28**. Also connected to frame **33** are circulation network **24**, mixing valve **26**, fuel tank **112**, and emergency (eyewash) fixture **37**, whether directly connected to frame **33** or indirectly through other parts of decontamination apparatus **20**. To move decontamination apparatus **20**, a user simply disconnects any fluid supply line **42** connected to fluid supply inlet. The user positions a foot on axle tube **51** and pulls handles **57** in direction **61**, lifting stand **36** from engagement with the ground or floor. The user can then move decontamination apparatus **20** by guiding handles **57** and rolling the apparatus using wheels **34**.

Other fixtures are possible and are within the scope of this disclosure. For example, a decontamination fixture having one or more sprayers or wands (not shown) may be included. Such a sprayer or wand could include a trigger or other actuator that can be actuated by a user. The sprayer or wand may include a spray nozzle to create a desired pattern of spray. A user can use such a sprayer or wand to direct the flow of fluid from the wand in a pattern and/or a direction selected by a user.

As shown in FIG. **3**, decontamination apparatus **320**, described in further detail below, is positioned on support **332**. Support **332** is a platform **333** upon which is positioned a heater **328**, emergency fixture **510**, and illustratively mixing valve **326**. Platform **333** includes a generally upwardly facing surface **335** sized to support heater **328** and emergency fixture **510** thereon. Support members **337** extend from platform **333** downwardly toward base **339**. Support members **337** are illustratively spaced apart from each other and are positioned to receive the tines of a fork truck, or other transportation or lifting device, therein to permit convenient transport of decontamination apparatus **320**. To move decontamination apparatus **320** from one location to another, any fluid supply lines, drain lines, and fuel (or other power source) lines are disconnected, and transportation or lifting device (not shown) is positioned in spaces between support members **337** and platform **333** is lifted so that support **332** and decontamination apparatus **320** are elevated above the ground or floor. Decontamination apparatus **320** is then moved to the desired location.

While decontamination apparatus **20** of FIG. **1** and decontamination apparatus **320** of FIG. **3** are illustrative examples configured for convenient transport, using frame **20** of FIG. **1** and using a fork-truck or similar device to transport apparatus

320 of FIG. 3, it is understood that other configurations are within the scope of this disclosure. Other portable, semi-portable, and non-portable configurations are contemplated. A self-contained fluid supply vessel may be provided instead of using water from a source such as a well, municipal water supply, or other similar water source. Such an apparatus could be transported using a transportation device such as a truck, automobile, military vehicle, train, helicopter, or other mode of transportation. A decontamination apparatus such as apparatus 320 of FIG. 3 could be affixed using known methods to a structure in a building, for example, if portability of the apparatus is not desired.

In one configuration rather than having a burner, heating element 314 is provided in an electric heater that enables a user to set the temperature of hot water in the hot water supply to achieve and maintain a higher temperature than is possible with typical residential water heater heating elements. In one exemplary configuration, a tubular heating element manufactured by Watlow Electric Manufacturing Company, 12001 Lackland Road, St. Louis, Mo., USA 63146 is capable of maintaining water at and above 180 degrees F. at typical flows for a sufficient time to satisfy requirements for emergency applications. Such heating elements are typically constructed to withstand higher temperatures and currents than standard residential heating elements. Further, thermostats associated with such heating elements are constructed to permit a user to select a temperature above about 185 degrees F.

Referring to FIG. 4, diffuser 30 includes a first conduit 60 and a second conduit 62 surrounding, illustratively, a majority of first conduit 60. First conduit 60 includes a first end 64 serving as an inlet of fluid to diffuser 30, and an opposite second end 66. Second conduit 62 includes a first end 74 serving as an outlet for fluid from diffuser 30 and an opposite second end 76. As illustrated in FIG. 4, a cap 68 is coupled to second end 76 to close second conduit 62. Cap 68 is coupled to second end 76 illustratively with solder applied around the perimeter of cap 68. It is understood that this diffuser design is illustrative only and that it is within the scope of this disclosure for diffusers to be different in design.

In the illustrative embodiment, diffuser 30 includes a union 70 to assist in positioning first conduit 60 relative to second conduit 62 and to assist in directing or guiding the flow of fluid through diffuser 30. Union 70 is coupled to first ends 64, 74 of respective first and second conduits 60, 62, illustratively with solder. Union 70 includes, at a first end 71 thereof, a first opening 72 to receive first end 74 of second conduit 62. Union 70 includes, at a second end 73 thereof, a second opening 78 sized to receive first end 64 of first conduit 60.

Referring to FIG. 4, in operation, fluid enters diffuser 30 through first end 64 of first conduit 60 adjacent second end 73 of union 70. Depending on the outlet configuration (described in more detail below), fluid generally flows in first direction 80 through first conduit 60 from its first end 64 to its second end 66. Second end 66 is spaced apart from cap 68, permitting fluid to exit second end 66 of first conduit 60 and reverse its direction to flow in a second direction 82, opposite first direction 80. First conduit 60 is positioned substantially within second conduit 62 so that when fluid exits second end 66, the fluid remains within the volume defined by cap 68, second conduit 62, and portions of union 70.

As shown in FIG. 4, union 70 includes, between its first and second ends 71, 73, a reducing region 75 that necks down or reduces the diameter of union 70 from a diameter sized to receive the outside diameter of second conduit 62 to a diameter sized to receive the outside diameter of first conduit 60, thus forming a seal to prevent fluid from flowing from second conduit 62 out of the fluid circulation network between first conduit 60 and second end 73 of union 70. Union 70 includes an outlet 86 formed between first end 71 thereof and reducing region 75. Illustratively, reducing region 75 is frustoconical in shape. An outlet 86 surrounds an opening 88 formed in union 70 to permit fluid flowing in direction 82 to exit diffuser 30 and flow toward mixing valve 26.

As illustrated in FIGS. 4 and 5, optional spacers 89 are positioned between the conduits to discourage relative movement therebetween. Illustratively, spacers 89 are positioned adjacent second end 66 of first conduit 60 and about the circumference of first conduit 60 to maintain the relative position of first and second conduits 60, 62. Spacers 89 are illustratively constructed using crimped pieces of copper alloy tubing commonly used in the plumbing industry. If included, spacers 89 may, however, be constructed using any suitable material(s) and may have any shape sufficient to maintain the relative position of conduits in a diffuser such as diffuser 30 and still permit adequate flow of fluid therethrough.

A first diffuser outlet configuration is depicted in diffuser 30 of FIG. 4. A series of apertures 90, designated individually as 90A through 90K, are formed in first conduit 60 at various positions around first conduit 60 and along its length. Apertures 90A, B, and C are formed in, approximately, the first half 92 of the length of first conduit 60. Apertures 90D through K are positioned in, approximately, the second half 94 of the length of first conduit 60. Because apertures 90A through 90K are positioned along the length of first conduit 60, portions of fluid flowing through first conduit 60 exit through apertures 90 and mix with fluid flowing outside of first conduit 60 and in second conduit 62. Illustratively, conduit 60 has an inside diameter of about 0.8 inches and has an overall length C of about 29 inches, and conduit 62 has an inside diameter of about 1.25 inches and has an overall length A of about 24.25 inches. Second end 66 is spaced apart from cap 68 by a distance of B, illustratively about 0.75 inches. However, it is understood that other sizes for conduit 62 are within the scope of this invention.

As 'fresh' hot fluid (a second mass of fluid) that has been recently heated by heater 28 first flows through first conduit 60, the fresh hot fluid mixes with the previously stagnant fluid that was in first conduit 60 and is in second conduit 62. Because apertures 90A-90J are provided along the length of first conduit 60, some of the fresh hot fluid flows through the first apertures 90 (for example 90A, 90B and 90C) encountered by the fluid flow without flowing all the way to second end 66 of conduit 60, thus blending the fluid and rendering the blended fluid a temperature between the temperature of the second mass of fluid and the stagnant fluid (a first mass of fluid) temperature. As more fresh hot fluid flows into first conduit 60, the blended temperature gradually approaches that of the fresh hot fluid. By blending the fluids as such, the fresh hot fluid does not reach mixing valve 26 at full temperature all at once, but rather reaches mixing valve 26 blended with previously stagnant fluid, thus providing the mixing valve a gradual increase in fluid temperature instead of the more immediate increase obtained without this blending.

First diffuser outlet configuration depicted in FIG. 4 illustrates apertures 90A through 90J formed as holes in first conduit 60 on generally opposite sides of the conduit, formed, for example, by drilling through a first point along the length of first conduit 60 and permitting the drilling device to penetrate through the opposite side of the conduit. It is understood, however, that any number of apertures 90A through 90J may be provided along the length and circumference of conduit 60. In the illustrative embodiment, aperture 90A is positioned about 13 inches from first end 64. Aperture 90B is positioned about 17 inches from first end **64**. Aperture **90**C is positioned about 19 inches from first end **64**. Aperture **90**D is positioned about 21 inches from first end **64**. Aperture **90**E is positioned about 1 inch from aperture **90**D. Apertures **90**F through **90**K are each positioned from the immediately adjacent aperture approximately the same distance as apertures **90**D and **90**E are spaced apart. Illustratively, apertures **90**A-J are holes drilled through conduit **60** so that a pair of holes, each 180 degrees around the circumference of conduit **60** from the other, is at each position along the length of first conduit **60**. Illustratively, apertures **90** are holes of 0.125 inch diameter drilled in conduit **60**; however, apertures **90**A-J may be of different sizes and shapes and each may be different from one or more other apertures.

Although certain illustrative outlet configurations are disclosed herein, it is within the scope of this disclosure to use any suitable shape of aperture or combination of shapes. It is also within the scope of this disclosure to space a wide range of sizes and numbers of such apertures **90** apart from one another by various distances to achieve a desired mixing of fluid inside an internal conduit with the fluid outside the internal conduit, and to maintain adequate flow through the diffuser. By way of example, additional outlet configurations are depicted in FIGS. **8** through **13**.

As shown in FIGS. **1** and **2**, a portion of hot fluid line **48** passes adjacent heater **28** to receive heat generated by heater **28** and heat the fluid flowing through hot fluid line **48**. Illustratively, hot fluid line **48** is constructed of a copper alloy; however, use of other suitable materials are within the scope of this disclosure. For example, steel, aluminum, brass, stainless steel, and other alloys or materials that have desirable characteristics such as adequate strength, durability, corrosion resistance, and high heat transfer rates, and are suitable in particular applications.

As shown in FIG. **2**, illustrative heater **28** includes a heat exchange chamber **806** through which hot fluid line **48** passes with cool fluid entering through portion **810** of hot fluid line **48** and exiting through portion **807**. Illustrative heat exchange chamber **806** is sized to receive burner **114** in its base region **122**. Heat exchange chamber **806** is illustratively rectangular in shape and has a plurality of fins **124** extending from a first side wall **126** to a second, opposite side wall **128**. As shown in FIG. **1**, heater **28** includes a flue **130**, the bottom **132** of which is sized to approximate the size of top **134** of draught diverter **805**, the bottom **840** of which is coupled to the top **842** of heat exchange chamber **806**. Excess heat and exhaust from the combustion process passes from heat exchange chamber **806** through flue **130** and exits through top **136** of flue **130** to the atmosphere or other suitable destination. A suitable heater **28** is available in the form of a water heater model number 125 FX from Robert Bosch Corporation, Broadview, Ill., USA, although other heat exchangers are suitable, as are known in the art. An additional suitable heater is available in the form of a water heater model no. GWH 425 HNO, also from Robert Bosch Corporation.

As shown in FIG. **1**, heater **28** includes a fuel line **110** coupled to fuel tank **112**. The burner **114**, shown in FIG. **2**, is sized to fit within the bottom **844** of heat exchanger **806** and couples to a fuel valve **814** that is configured to control the flow of fuel from fuel line **110** to burner **114**. Illustratively, fuel valve **814** is responsive to a controller system **118**, shown and described in more detail below with reference to FIGS. **16** and **17**, or may have a manual control such as on/off switch **833**, by which fuel valve **814** opens upon certain conditions to provide fuel. If on/off switch **833** is used, the switch may be accessed through opening **803** in cover **801**, which fits around heat exchange chamber **806**, burner **114**, and fuel valve **814**. Fuel is supplied via ports **835** and **836** and, illustratively, controller-system **118** and fuel valve **814** cooperate to open fuel valve **814** and ignite fuel at burner **114** when actuator **41** is actuated by a user. It is within the scope of this disclosure for a variety of types of equipment to be used instead of or in addition to controller system **118** to determine whether, for example, power or fuel to heater **28** should be increased, or whether heater **28** should be started or ignited. For example, a typical flow sensor could be incorporated to detect flow of fluid in hot fluid line **48**, and when flow is detected in line **48**, heater **28** is ignited. Further, a thermocouple to detect the temperature of fluid flowing through hot fluid line **48** could likewise be incorporated. If fluid was flowing through hot fluid line **48** and the thermocouple detected a temperature below a set point, heater **28** could be started or otherwise turned up. It is understood that heater **28** is illustrative, and other heater configurations are within the scope of this disclosure.

As illustrated in the diagram of FIG. **16**, cold fluid entering the heater passes through a valve assembly that allows gas to enter the burners only when fluid is flowing. A fluid flow sensor **728** signals computer **729** to light burner **732**, and the gas is ignited in the illustrative gas-fueled example by the pilot or spark ignition. Illustratively, burners **732** activate at a flow rate of 0.75 gallons per minute (GPM), with about 0.6 gpm continuous flow required to maintain burners **732** lit. Fluid is heated as it flows through heat exchanger **730**, which illustratively includes finned tube copper coils located adjacent burners **732**. As the fluid flow rate changes, a governor (not shown) modulates the flow of gas to burners **732** to maintain a constant temperature. The size of the flames and the energy used is thus proportional to the volume of hot fluid being moved through the system. The fluid temperature can be adjusted, illustratively from about 100.degree. to about 140.degree. F., by adjusting gas proportioning valve **734**.

Referring to FIGS. **14** and **15**, a flame sensor **620** of heater **28** (shown in FIGS. **1** and **2**) optionally may be positioned on pilot assembly **621** to sense when a flame **622** is present (FIG. **15**), and to shut off the supply of gas upon failure of flame **622** (FIG. **14**). As shown in FIG. **17**, optionally a flue gas sensor **713**, a high temperature limiter **707**, and an overheat sensor **706** illustratively positioned in the flue, are coupled in series to an electronic control box **708**, that controls a valve (not shown), the valve closing upon a signal from any one or more of these sensors to stop the flow of gas. Flow sensor **728**, shown in FIG. **16** senses when the flow of fluid is stopped, similarly signaling to close a valve and shut off the flow of gas to the burners. Illustratively, heater **28** includes a push button piezo-electric pilot **624** shown in FIGS. **14** and **15**, and as **705** in FIG. **17**, safety interlocked controls, and an illustrative copper heat exchanger **730** illustrated in FIG. **16**. Further, illustratively heater **28** includes a slow ignition valve, high-efficiency low-maintenance stainless steel burners **732**, and filters (not shown) for the pilot and burners to provide clogging protection.

An alternative embodiment of a diffuser **230** is illustrated in FIG. **5**. Diffuser **230** is illustrated as a three-pass diffuser and includes first conduit **232**, a second conduit **234**, and a third conduit **236**. As shown in FIG. **5**, first conduit **232** is positioned substantially within second conduit **234**, and second conduit **234** is positioned substantially within third conduit **236**. A first union **238** cooperates with first, second, and third conduits **232**, **234**, **236** to maintain the conduits in position. First union **238** includes a first section **240** and a second section **242**. First section **240** includes a smaller diameter opening **244** sized to receive first conduit **232** therein. First section **240** includes a larger diameter opening **246** sized to receive the second conduit **234** therein. First section **240** includes a reducing or neck down region **248** between openings **244** and **246**. Illustratively, reducing region **248** is frustoconical in shape. Second section **242** includes a smaller diameter opening **250** sized to receive the second conduit **234**. Second section **242** includes a larger diameter opening **252** sized to receive the outside diameter of third conduit **236**. Second section **242** includes a reducing or neck down region **254** between openings **250** and **252**. Illustratively, reducing region **254** is frustoconical in shape. First section **240** and second section **242** of first union **238** may be provided as two separate pieces or may optionally be formed as a single first union part.

Diffuser **230** further includes a second union **256** spaced apart from first union **238**. Second union **256** includes a larger diameter opening **258** sized to receive an outlet end **260** of third conduit **236**. Second union **256** includes a smaller diameter opening **262** sized for coupling to a hot fluid line **264**. Second union **256** includes a reducing or neck down region **266** between openings **258**, **262**. Illustratively, reducing region **266** is frustoconical in shape. End cap **226** has a side **227** sized to receive a second end **239** of second conduit **324**.

While the reducing regions described above are shown and described as being frustoconical in shape, it is within the scope of this disclosure for one or more of the reducing regions to be other shapes. Further, although unions are described as being separate components from the conduits, it is within the scope of this disclosure to form diffusers from any number of pieces or to mold diffusers from a single piece. One of ordinary skill in the art will recognize that a wide variety of formation and/or assembly techniques may be implemented to make a diffuser.

First conduit **232** has a length F, illustratively about 53-54 inches. Second conduit **234** has a length E, illustratively about 50-51 inches. Third conduit **236** has a length D, illustratively about 48 inches. Illustratively, first, second, and third conduits **232**, **234**, **236** have inside diameters of about 1, 1.5, and 2.5, inches respectively. Diffuser **230** outlet configuration depicted in FIG. **5** illustrates apertures **290**A through **290**Q formed as holes in first conduit **232** and second conduit **234**, each hole illustratively having a second corresponding hole on generally opposite sides of the conduit, formed, for example, by drilling through a first point along the length of the conduit and permitting the drilling device to penetrate through the opposite side of the conduit. While two opposite holes are described for each of apertures **290**A through **290**Q, such is illustrative, and any number of holes of any shape are within the scope of this invention.

The sizes and spacing of the apertures **290** are described for illustrative purposes herein. As shown, illustrative apertures **290**A are 7/64 inch holes positioned in first conduit **232** about 12 inches from first end **233** of first conduit **232**. apertures **290**B are 3/32 inch holes positioned about 24 inches from first end **233**, apertures **290**C are 5/64 inch holes positioned about 36 inches from first end **233**, apertures **290** Dare 1/16 inch holes positioned about 48 inches from first end **233**, and apertures **290**E are 1/16 inch holes positioned about 2 inches from second end **235**.

Still referring to FIG. **5**, illustrative apertures **290**F are 9/16 inch holes positioned about 3.5 inches from first end **237** of second conduit **234** or adjacent the reducing region **254** of the second section **242** of first union **238**. Illustrative apertures **290**G are 9/16 inch holes positioned about 4.0 inches from first end **237** of second conduit **234**, and are rotated 90 degrees around the circumference of second conduit **234** relative to apertures **290**F. Illustrative apertures **290**H are 9/16 inch holes positioned about 4.5 inches from first end **237** of second conduit **234**, and are rotated 90 degrees around the circumference of second conduit **234** relative to apertures **290**G. Illustrative apertures **2901** are 9/16 inch holes positioned about 5.0 inches from first end **237** of second conduit **234**, and are rotated 90 degrees around the circumference of second conduit **234** relative to apertures **290**H. Illustrative apertures **290**J are 9/16 inch holes positioned about 5.5 inches from first end **237** of second conduit **234**, and are rotated 90 degrees around the circumference of second conduit **234** relative to apertures **290**L. Illustrative apertures **290**K are 9/16 inch holes positioned about 6.0 inches from first end **237** of second conduit **234**, and are rotated 90 degrees around the circumference of second conduit **234** relative to apertures **290**J. Illustrative apertures **290**L are 9/16 inch holes positioned about 6.5 inches from first end **237** of second conduit **234**, and are rotated 90 degrees around the circumference of second conduit **234** relative to apertures **290**K. Illustrative apertures **290**M are 9/16 inch holes positioned about 7.0 inches from first end **237** of second conduit **234**, and are rotated 90 degrees around the circumference of second conduit **234** relative to apertures **290**L. Illustrative apertures **290**N are 3/32 inch holes positioned about 38.0 inches from second end **239** of second conduit **234**. Illustrative apertures **290**P are 3/32 inch holes positioned about 20.0 inches from second end **239** of second conduit **234**. Illustrative apertures **290**Q are 3/32 inch holes positioned about 20.0 inches from second end **239** of second conduit **234**.

It is understood that fluid entering diffuser **230** at first end **233** of first conduit **232** flows upward to end cap **226**, then flows downward between first conduit **232** and second conduit **234**, down to aperture **290**F, and then flows upward again between second conduit **234** and third conduit **236**, up to and out through hot fluid line **264**. As fluid flows past each of the apertures **290**A through **290**Q, newly heated fluid may flow through the apertures to mix with stagnant water that may already be in diffuser **230**.

An alternative heater embodiment, heater **328**, is depicted in FIG. **3**. Heater **328** is a standard "residential" water heater, illustratively a 119 gallon water heater including a fuel line **310** coupled to fuel tank **312** and burner **314**. A fuel valve (not shown) may be coupled to fuel line **310** to control flow of fuel to burner **314**, and may be responsive to a controller (not shown) to provide fuel when the controller senses that additional heat is to be supplied to increase the temperature of fluid stored in heater **328**. Many fuels may be used, for example natural gas, propane, or other suitable fuel types. In addition, more than one fuel tank **312** may be used at the same time to provide more fuel to burner **314** than one fuel tank **312** could provide alone. One of ordinary skill in the art will appreciate that an electric water heater could be used for illustrative heater **328**.

Heater **328** further includes a storage tank **302** in which fluid is stored that enters storage tank **302** through a fluid inlet line **340**. As shown in FIG. **3**, a heat exchange region **321** includes an interface **323** adjacent burner **314**. Interface **323** may take a number of forms, and may include a circuit through which hot combustion gases flow such as a coil, a generally flat surface, or a heat sink extending into fluid stored in storage tank **320** to increase the surface area of interface **323** in contact with fluid in storage tank **320**. If heater **328** is an electric heater, an electric element electrically coupled to an electric source could heat the fluid in storage tank **320**. Optionally, a filter **347** may be provided, illustratively in fluid inlet line **340**, to filter out particulate matter. Filters may be provided elsewhere in the system, illustratively in cold fluid line **346**.

As shown in FIG. **3**, a mixing valve **326** receives hot fluid from hot fluid line **348** and cold fluid from cold fluid line **346**. As with the embodiment described with reference to FIG. **1**, mixing valve **326** mixes hot and cold fluids and supplies tempered water through mixed fluid line **350**. A diffuser, illustratively diffuser **230** of FIG. **5**, is coupled to hot fluid inlet line **348** and is between mixing valve **326** and the fluid outlet from heater **328**. An illustrative mixing valve is disclosed in U.S. Pat. No. 5,647,531 assigned to Lawler Manufacturing Company, Inc. of Indianapolis, Ind., the disclosure of which is hereby incorporated by reference herein. Other mixing valves of various configurations may be used depending on the specific requirements of the application in which the subject matter hereof is incorporated.

In an embodiment of decontamination apparatus **320** shown in FIG. **24**, a heat trap **365** may be positioned within cold fluid line **346**. The arrows in FIG. **24** represent the directions of fluid flow. Heat trap **365** may operate to prevent or reduce thermosyphoning (energy losses) of hot water from heater **328** during periods of no active fluid flow. In an exemplary embodiment, heat trap **365** is a portion of copper conduit positioned within cold fluid line **346** as an inverted "U" shape, wherein a horizontal portion of cold fluid line **346** curves upwards, curves back to a horizontal position in the same or substantially similar direction as the initial horizontal direction, curves downwards parallel or substantially parallel to the initial upward direction, and then curves back to a horizontal position in the same or substantially similar direction as the prior horizontal direction, forming an inverted "U" shaped heat trap **365**. It is within the scope of this disclosure to use other heat trap means or systems as are known in the art to reduce energy losses of hot water during periods of no active fluid flow.

It is within the scope of this embodiment that one or more pressure reducing valves **63** may be positioned either directly adjacent to mixing valve **26** or prior to an inlet of mixing valve within cold fluid line **46** and/or cold fluid line **48**.

A restrictor **349** (internal location as shown in FIGS. **3** and **21**), may be positioned between the junction of cold fluid line **346** and cold inlet of mixing valve **326**. Restrictor **349** may also define one or more holes. In one embodiment, restrictor **349** may be comprised of copper, be circular in shape, 1¼" in diameter, $^{10}/_{100}$" ($^{1}/_{100}$") thick, and define a hole $^{3}/_{16}$" in diameter. Restrictor **349** may be comprised of metal, plastic, glass, or other suitable materials, may be sized and shaped with diameters and thicknesses suitable for the particular application, and may define one or more holes of varying diameters. Restrictor **349** operates to equalize differentials in pressure between cold fluid line **346** and hot fluid line **348** from heater **328** to mixing valve **326**. Restrictor **349** is therefore beneficial by equalizing pressures of cold fluid line **346** and hot fluid line **348** entering mixing valve **326** to stop mixing valve **326** from going into bypass, allowing only cold fluid from cold fluid line **346** to flow through mixing valve **326**. Accordingly, if fluid pressure is zero or too low from the hot fluid line **348**, the mixing valve **326** may revert to bypass blocking off the hot fluid from the hot fluid line **348**, allowing only cold fluid from the cold fluid line **346** to flow through the mixing valve **326**. If fluid pressure is zero or too low from the cold fluid line **346**, mixing valve **326** may revert to bypass blocking off the flow of cold fluid from the cold fluid line **346** and hot fluid from the hot fluid line **48**, preventing all fluid flow through the mixing valve **326** so that hot fluid is not permitted to flow and perhaps injure the user. Additionally, if fluid pressure is too high from cold fluid line **346**, mixing valve **326** may only sense cold fluid and may revert to bypass blocking off the hot fluid from hot fluid line **348**. Restrictor **349**, when positioned between cold inlet of mixing valve **26**, would act in this latter fashion to prevent bypass by decreasing the pressure of the cold fluid from cold fluid line **346**. It is within the scope of this embodiment that a restrictor **349** may also be positioned between the junction of cold fluid line **346** and cold inlet of mixing valve **326**, with or without a restrictor **349** being positioned between the junction of hot fluid line **348** and mixing valve **326**.

While reference is made to restrictor **349**, it is within the scope of this disclosure to use other means or systems as are known in the art to reduce the pressure of fluid flow through a conduit, such as pressure reducing valves and the like. For example, as shown in FIG. **22**, pressure reducing valve **63** may be positioned within cold fluid line **346** prior to mixing valve **326**. Pressure reducing valve **63** may operate to equalize differentials in pressure between cold fluid from cold fluid line **346** and hot fluid from hot fluid line **348** to mixing valve **326** by restricting the pressure of cold fluid from cold fluid line **346**.

An additional embodiment, as shown in FIG. **23**, demonstrates an embodiment utilizing multiple pressure reducing valves. In this embodiment, pressure reducing valves **63** may be positioned within cold fluid line **346** prior to mixing valve **326** and may also be positioned within hot fluid line **348** prior to mixing valve **326**. Pressure reducing valves **63** may operate to equalize differentials in pressure between cold fluid from cold fluid line **346** and hot fluid from hot fluid line **348** to mixing valve **326** by restricting the pressure of cold fluid from cold fluid line **346** and the pressure of hot fluid from hot fluid line **348**. It is within the scope of this embodiment that one or more pressure reducing valves **63** may be positioned either directly adjacent to mixing valve **326** or prior to an inlet of mixing valve within cold fluid line **346** and/or cold fluid line **348**.

Aspects of an additional embodiment of decontamination apparatus **320** are shown in FIG. **25**. The arrows in FIG. **25** represent the directions of fluid flow. In this embodiment, cold fluid from cold fluid line **346** may flow to mixing valve **326** and/or to a second mixing valve **363**. Hot fluid from hot fluid line **348** may also flow to mixing valve **326** and/or to second mixing valve **363**. Mixed fluid may then flow from mixing valve **326** and/or second mixing valve **363** to emergency fixture **510** such as eyewash outlet fixture **520** and/or emergency shower fixture **530**. In this embodiment, if eyewash outlet fixture **520** is activated by a user, cold fluid from cold fluid line **346** and hot fluid from hot fluid line **348** may mix in mixing valve **326** and second mixing valve **363** and flow to eyewash outlet fixture **520**. Additionally, if emergency shower fixture **530** is activated by a user, cold fluid from cold fluid line **346** and hot fluid from hot fluid line **348** may mix in mixing valve **326** and second mixing valve **363** and flow to emergency shower fixture **530**. Second mixing valve **363** may predominantly supply mixed fluid to eyewash outlet fixture **520**, and therefore when eyewash outlet fixture **520** is activated (the emergency fixture **510** that has a relatively low fluid flow requirement), second mixing valve **363** may provide mixed fluid to eyewash outlet fixture **520**. It is understood in this additional embodiment that cold fluid from cold fluid line **346** and hot fluid from hot fluid line **348** may mix in one or both mixing valve **326** and second mixing valve **363** under all conditions of fluid flow out of an emergency fixture **510**. A preferred second mixing valve **363** is model no. 911EF, manufactured by Lawler Manufacturing Company, Inc.

Still referring to FIG. **3**, when a user actuates actuator **521**, **526**, or **532**, opening a valve **522**, **534**, mixed fluid flows from mixed fluid outlet of the mixing valve and through mixed fluid line **350**, toward fixture **510**.

As shown in FIGS. **3** and **6**, a combination emergency fixture **510** is illustrated. Emergency fixture **510** includes a tempered fluid inlet **512** receiving tempered water from a source such as the system shown in FIG. **3**. Emergency fixture **510** includes a fluid supply line **514** coupled to fluid inlet **512**, the fluid supply line being coupled to an eyewash supply line **516** and a emergency shower supply line **518**. Eyewash supply line **516** is coupled to an eyewash outlet fixture **520** so that, when eyewash actuator **521** and valve **522** is actuated, fluid flows from fluid inlet **512** through fluid supply line **514**, into eyewash supply line **516**, and out eyewash outlet fixture **520**. Basin **524** is provided to catch at least part of the refuse fluid and divert the discarded fluid into a drain line **525**. An optional foot actuator **526** is coupled with a link **528** to valve **522** so that a user can actuate the eyewash by stepping on foot actuator **526**. Combination emergency fixture **510** further includes an emergency shower fixture **530** coupled to the emergency shower supply line **518**. A shower actuator **532** is operably coupled to a valve **534** so that when a user actuates shower actuator **532**, tempered fluid flows from fluid inlet **512** through fluid supply line **514**, into emergency shower supply line **518**, and out emergency shower fixture outlet **536**.

It is within the scope of this disclosure for heaters **28**, **328** to be replaced with another suitable heating device, for example a shell and tube heat exchanger—having a heating fluid flowing therethrough (when access is had to such a heating fluid possessing sufficient heat to raise the temperature of supplied fluid by an acceptable amount).

Diffusers **30**, **230** are illustratively constructed using a copper alloy. In these examples, copper is selected because of its high heat transfer rate, and resultant ability to dissipate heat contained in fluid flowing through diffusers **30**, **230**. However, one of ordinary skill in the art will recognize that many other materials could be used that provide desirable properties such as machinability, durability, corrosion resistance, compatibility with other system materials, cost, and the like.

In a further illustrative embodiment represented in FIG. **7**, a conduit **410** is depicted. Conduit **410** may serve as the inner conduit of a diffuser, the outer conduit, or a conduit between the outer and inner conduit in a three (or more) pass diffuser. Conduit **410** includes an internal passageway **412** and an external surface **414**. As shown in FIG. **7**, external surface **414** includes a plurality of fins **416**. Fins **416** are actually shown as a single spiral fin created using an extrusion process in which a thick-walled, illustratively copper alloy, tube is extruded to form fins **416** from surface **414**. An integral finned surface **418** is thus formed on conduit **410**. Fins **416** increase the surface area of external surface **414** and thus increase heat transfer into adjacent matter such as fluid flowing outside of conduit **410**. It is within the scope of this disclosure to include a separate finned surface **418** constructed from a different piece of material than conduit **410** and connect separate finned surface **418** to conduit **410** to permit heat transfer during operation from conduit **410** into separate finned surface **418**. It is within the scope of this disclosure to form fins **416** independently instead of as a single, spiral fin. Conduit **410** could serve as an external conduit, middle conduit (such as in a three-pass diffuser configuration) or an inner conduit. A finned conduit may be used instead of or in addition to a conduit with plurality of apertures, or, alternatively, the finned conduit may be provided with one or more apertures, to provide additional mixing.

Referring now to FIGS. **8** through **13**, various aperture configurations are depicted for the apertures provided in the diffusers. These aperture configurations are provided on the internal conduits—in other words, depending on the number of passes fluid makes through a particular diffuse line, all conduits except for the outermost conduit may, or may not, include such aperture configurations. Any number of passes may be made through a diffuser, however consideration of physical, practical, and cost factors suggest that diminishing returns exist beyond a maximum number of passes. However, this maximum number of passes may vary depending on such factors as system size, pressure, and flow rate, for example. Generally, a higher number of passes should improve mixing between a first mass of fluid and a second mass of fluid adjacent the first mass upon entry into the diffuser. Further, a higher number of passes should improve heat transfer between such a first and second fluid mass, from the fluid mass(es) and to the diffuser material.

FIG. **8** shows a plurality of apertures **90** evenly spaced along the length of conduit **60**. FIG. **13** similarly shows a plurality of apertures **690**A through **690**E. However, apertures **690**A through **690**E are depicted as not evenly spaced. For example, Apertures **690**D and **690**E are more closely spaced than apertures **690**A and **690**B, and illustratively the spacing gradually decreases from **690**A to **690**E. A combination arrangement is shown in FIG. **4**, with spacing gradually decreasing in first half **92** from aperture **90**A to aperture **90**D, and the spacing remaining essentially consistent between apertures in second half **94**, from aperture **90**D to aperture **90**K. Apertures **95-98** in FIGS. **9-12** depict a variety of illustrative shapes including rhomboid, ovoid, rectangular, and parallelogram shapes. However, it is understood that these shapes are illustrative only, and that other shapes, including irregular shapes, may be included and are within the scope of this disclosure. Additionally, any shape aperture may be used with any aperture spacing to achieve the desired mixing effect of fluid in the conduit.

FIG. **8** illustrates substantially circular holes, FIG. **9** illustrates a substantially diamond (rhomboid) aperture, FIG. **10** illustrates a substantially oval aperture, FIG. **11** illustrates a substantially rectangular aperture, FIG. **12** illustrates an angularly-oriented parallelogram-shaped aperture, and FIG. **13** illustrates a series of apertures positioned at points A, B, C, D, and E along conduit **660**.

Diffusers **30**, **230** may also serve as heat sinks. The heat sink is a thermally conductive structure that has a mass per unit of linear length of net fluid flow greater than the average mass per unit of linear length of net fluid flow in the overall fluid flow network. Illustratively, the heat sink comprises copper. In one exemplary configuration, the heat sink surrounds a first fluid conduit such as conduits **60**, **232** of FIGS. **4** and **5**, so that fluid flowing from the first fluid conduit subsequently flows through a passageway defined by or otherwise through the heat sink. Further, while the diffusers illustrated herein are used in conjunction with portable emergency fixtures, it is understood that the diffusers may be used with any fixture for which temperature control is desired. Such fixtures include fixed stationary emergency fixtures, as well as sinks, showers, and any other fluid fixture. The diffusers illustrated herein may also be used in combination with hot water heaters, for whatever purpose, wherein the diffuser would be installed in the hot water line exiting from the hot water heater. Other applications for the diffusers are possible.

The following chart contains data from a test performed using a diffuser similar to the diffuser shown in FIG. 3:

EXAMPLE 1

Time	Temperature (° F.) of Cold Water	Temperature (° F.) of Hot Water	Temperature (° F.) of Mixed Water	Pressure of water at mixing point
3:00:42 PM	43.4509	171.7	84.6336	1.92
3:00:52 PM	43.3573	171.924	84.8198	3.02
3:01:02 PM	43.3417	172.67	85.6164	6.55
3:01:12 PM	43.4275	173.252	144.085	6.40
3:01:22 PM	43.4119	173.739	165.607	7.14
3:01:32 PM	43.4275	174.084	169.902	6.42
3:01:42 PM	43.4509	174.396	171.483	7.07
3:01:52 PM	43.5757	174.592	171.985	6.91
3:02:02 PM	44.0981	174.896	172.683	6.65
3:02:12 PM	45.1031	175.031	172.92	6.81
3:02:22 PM	46.2003	175.024	173.34	7.12
3:02:32 PM	47.0322	175.207	173.489	7.12
3:02:42 PM	47.7779	175.274	173.638	7.11
3:02:52 PM	48.3911	175.301	173.807	6.98
3:03:02 PM	45.5001	175.288	173.699	3.03
3:03:12 PM	44.2462	175.031	121.81	2.32
3:03:22 PM	44.1292	174.592	95.1776	1.99
3:03:32 PM	43.9032	174.497	91.0316	2.85
3:03:42 PM	43.9655	174.166	89.2846	3.01
3:03:52 PM	44.1994	173.936	88.4988	1.58
3:04:02 PM	43.7784	173.821	87.9795	2.06
3:04:13 PM	43.5133	173.631	87.8607	2.73
3:04:23 PM	43.3495	173.577	87.6083	1.67
3:04:33 PM	43.2715	173.36	83.1573	1.27
3:04:43 PM	43.1544	173.266	81.656	1.91
3:04:53 PM	43.131	173.184	81.2523	1.39
3:05:03 PM	43.0842	173.089	81.1551	2.66
3:05:13 PM	43.0452	173.029	80.9755	2.32
3:05:23 PM	42.9437	172.981	80.9306	0.05
3:05:33 PM	42.9906	172.758	81.1326	0.03
3:05:43 PM	43.014	172.649	81.3495	0.03
3:05:53 PM	43.014	172.52	82.1269	0.03
3:07:30 PM	45.8493	170.537	84.7979	0.03
3:07:32 PM	45.966	170.537	84.7979	0.03
3:07:35 PM	46.0516	170.496	84.783	0.03
3:11:16 PM	45.6476	164.755	89.4627	0.03
3:11:26 PM	45.7643	164.618	89.3071	0.03
3:11:36 PM	45.7176	164.434	89.1515	0.03
3:11:46 PM	45.7487	164.243	89.0329	0.03
3:11:56 PM	45.9277	165.308	97.7428	6.52
3:12:06 PM	47.0629	166.746	148.545	6.84
3:12:16 PM	47.3194	168.571	159.367	6.98
3:12:26 PM	47.2727	170.29	162.992	6.92
3:12:36 PM	47.3349	170.752	165.43	5.59
3:12:46 PM	46.2389	170.847	159.882	2.24
3:12:56 PM	46.0678	170.989	106.999	3.43
3:13:06 PM	46.06	171.111	99.4216	3.38
3:13:16 PM	45.8733	171.478	97.6253	2.34
3:13:26 PM	45.492	171.762	93.4761	2.47
3:13:36 PM	45.0872	172.068	92.192	2.40
3:13:46 PM	44.5108	172.244	91.8522	2.85
3:13:56 PM	44.1991	172.461	91.5567	1.63
3:14:06 PM	43.934	172.616	91.2092	2.70
3:14:16 PM	43.8405	172.691	91.1279	3.16
3:14:26 PM	43.7859	172.766	91.0466	1.84
3:14:36 PM	43.7079	172.874	88.8771	3.14
3:14:46 PM	43.7157	172.942	88.5583	2.85
3:14:56 PM	43.6767	172.921	88.3432	2.49
3:15:06 PM	43.6303	172.981	88.343	2.31
3:15:16 PM	43.5835	172.893	88.573	2.65
3:15:26 PM	43.5211	172.873	88.573	1.64
3:15:36 PM	43.4197	172.866	88.5136	3.12
3:15:46 PM	43.3417	172.839	88.0759	2.40
3:15:56 PM	43.2559	172.656	76.8887	2.40
3:16:06 PM	43.209	172.534	76.9037	1.41
3:16:16 PM	43.2012	172.5	80.2271	0.03
3:16:26 PM	43.209	172.331	80.1597	1.91
3:16:36 PM	43.2246	172.737	91.7855	7.00

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Time	Temperature (° F.) of Cold Water	Temperature (° F.) of Hot Water	Temperature (° F.) of Mixed Water	Pressure of water at mixing point
3:16:46 PM	43.2246	173.238	157.181	7.02
3:16:56 PM	43.2246	173.672	168.195	6.79
3:17:06 PM	43.2402	173.956	170.493	6.81
3:17:16 PM	43.2559	174.301	171.585	6.93
3:17:26 PM	43.2793	174.423	172.222	6.69
3:17:37 PM	43.3105	174.653	172.859	6.98
3:17:47 PM	43.3963	174.72	171.266	0.03
3:17:57 PM	43.6069	174.639	170.88	0.03
3:18:07 PM	43.9804	174.581	170.149	0.03
3:18:17 PM	44.6039	173.552	170.522	1.87
3:18:27 PM	44.1987	173.187	116.597	3.45
3:18:37 PM	44.1753	173.816	105	4.21
3:18:47 PM	44.2299	173.776	107.761	6.24
3:18:57 PM	44.2299	173.952	142.44	5.79
3:19:07 PM	44.1831	174.08	158.029	5.79
3:19:17 PM	44.261	174.33	160.143	5.79
3:19:27 PM	44.339	174.303	154.455	5.66
3:19:37 PM	44.3623	174.249	150.432	5.59
3:19:47 PM	44.3857	174.445	149.94	5.84
3:19:57 PM	44.5805	174.398	148.83	0.03
3:20:07 PM	44.6221	174.299	118.859	0.03
3:20:17 PM	44.2714	174.218	71.4021	0.03
3:20:27 PM	44.1389	173.541	61.8197	0.03
3:20:37 PM	43.9804	172.353	65.3808	0.03
3:20:47 PM	43.9596	172.823	75.4319	0.45
3:20:57 PM	43.8511	173.112	81.5016	4.65
3:21:07 PM	43.8667	173.343	88.7164	5.76
3:21:17 PM	43.8511	173.674	138.142	5.57
3:21:27 PM	43.8433	173.959	146.358	5.96
3:21:37 PM	43.8667	174.182	149.282	5.31
3:21:47 PM	43.8979	174.5	150.273	5.76
3:21:57 PM	43.9758	174.561	150.717	6.08
3:22:07 PM	43.9836	174.466	151.014	5.63
3:22:17 PM	44.0304	174.594	151.346	4.22
3:22:27 PM	44.0772	174.635	139.776	3.73
3:22:37 PM	44.0694	174.703	124.316	4.40
3:22:47 PM	44.0304	174.79	124.216	4.73
3:22:57 PM	43.9914	174.703	126.607	4.47
3:23:07 PM	43.9914	174.689	126.919	4.56
3:23:17 PM	44.007	174.689	127.792	4.28
3:23:27 PM	44.0304	174.676	130.123	4.98
3:23:37 PM	44.007	174.723	131.121	4.50
3:23:47 PM	44.0304	174.696	132.166	5.07
3:23:57 PM	44.0227	174.729	134.944	5.15
3:24:07 PM	43.9838	174.675	135.331	0.03
3:24:17 PM	43.8045	174.587	107.9	0.03
3:24:27 PM	43.6485	174.181	55.0661	0.03
3:24:37 PM	43.5939	174.235	47.9435	1.58
3:24:47 PM	43.5159	172.557	55.5128	2.60
3:24:57 PM	43.4613	172.855	74.6183	1.94
3:25:07 PM	43.4223	173.207	74.5957	1.31
3:25:17 PM	43.3989	173.098	74.4224	2.68
3:25:27 PM	43.3911	172.882	78.4307	4.91
3:25:37 PM	43.4067	173.173	110.219	5.20
3:25:47 PM	43.4613	173.491	129.762	5.08
3:25:57 PM	43.4691	173.64	133.013	5.20
3:26:07 PM	43.5003	173.87	133.852	5.08
3:26:17 PM	43.5471	174.127	134.282	5.31
3:26:27 PM	43.6173	174.093	134.627	5.25
3:26:37 PM	43.5939	174.033	134.951	5.44
3:26:47 PM	43.5861	174.107	135.036	0.60
3:26:57 PM	43.5401	173.962	98.6244	0.03
3:27:07 PM	43.4387	173.82	56.8212	0.03
3:27:17 PM	43.3997	173.482	48.0761	0.03
3:27:27 PM	43.3451	173.313	45.628	0.03
3:27:38 PM	43.2593	173.164	47.3618	0.03
3:27:48 PM	43.2359	171.741	55.3284	0.03
3:27:58 PM	43.2124	171.476	59.6308	0.03
3:28:08 PM	43.1968	171.32	56.2213	0.03
3:28:18 PM	43.1344	171.144	48.1149	0.03
3:28:28 PM	43.111	170.981	44.8494	0.03
3:28:38 PM	43.0564	170.927	44.0781	0.03
3:28:48 PM	43.0252	170.757	43.8598	0.03
3:28:58 PM	42.994	170.52	44.4911	0.03

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Time	Temperature (° F.) of Cold Water	Temperature (° F.) of Hot Water	Temperature (° F.) of Mixed Water	Pressure of water at mixing point
3:29:08 PM	42.955	170.18	49.4645	0.03
3:29:18 PM	42.9471	169.895	50.7347	0.03
3:29:28 PM	42.9003	169.691	51.0674	0.03
3:29:38 PM	42.9342	169.374	51.2093	0.03
3:29:48 PM	42.8938	169.229	51.1929	0.03
3:29:58 PM	42.9016	168.963	51.1233	4.77
3:30:08 PM	42.9407	170.139	90.075	4.94
3:30:18 PM	42.9407	170.703	123.685	5.31
3:30:28 PM	42.9641	171.347	129.39	5.37
3:30:38 PM	43.0187	172.012	131.364	4.60
3:30:48 PM	43.0655	172.52	130.601	4.84
3:30:58 PM	43.0967	172.947	130.601	5.21
3:31:08 PM	43.1514	172.906	130.983	5.20
3:31:18 PM	43.1358	172.798	131.315	4.88
3:31:28 PM	43.1748	173.17	131.647	4.61
3:31:38 PM	43.206	173.698	131.704	5.07
3:31:48 PM	43.2372	174.064	131.739	4.94
3:31:58 PM	43.2684	174.287	131.986	4.51
3:32:08 PM	43.3152	174.402	132.276	5.23
3:32:18 PM	43.323	174.442	132.445	5.08
3:32:28 PM	43.3698	174.524	132.636	4.23
3:32:38 PM	43.4322	174.483	132.706	5.11
3:32:48 PM	43.4406	174.515	132.663	4.55
3:32:58 PM	43.4874	174.488	132.536	4.58
3:33:08 PM	43.503	174.508	132.536	5.14
3:33:18 PM	43.5186	174.508	132.472	4.33
3:33:28 PM	43.5498	174.535	124.097	4.83
3:33:38 PM	43.5654	174.596	136.853	5.53
3:33:48 PM	43.5888	174.657	143.873	5.07
3:33:58 PM	43.6512	174.623	146.047	5.39
3:34:08 PM	43.6512	174.664	146.339	5.77
3:34:18 PM	43.6902	174.731	146.443	5.84
3:34:28 PM	43.7447	174.657	146.589	5.72
3:34:38 PM	43.7993	174.738	146.624	5.65
3:34:48 PM	43.8461	174.779	148.618	5.48
3:34:58 PM	43.9007	174.846	152.621	5.61
3:35:08 PM	43.9163	174.826	153.16	5.58
3:35:18 PM	43.9708	174.738	153.36	6.05
3:35:28 PM	44.002	174.813	153.395	5.26
3:35:38 PM	44.0569	174.818	153.463	5.28
3:35:48 PM	44.1192	174.872	153.47	5.98
3:35:58 PM	44.1816	174.859	153.504	5.84
3:36:08 PM	44.2544	174.895	153.514	4.46
3:36:18 PM	44.2934	174.875	151.779	4.84
3:36:28 PM	44.309	174.712	139.422	3.03
3:36:38 PM	44.3012	174.679	116.732	2.69
3:36:48 PM	44.2778	174.374	108.42	2.70
3:36:58 PM	44.2154	174.178	101.754	0.76
3:37:08 PM	44.1843	174.023	99.4504	1.08
3:37:18 PM	44.1609	173.671	95.4277	1.91
3:37:29 PM	44.1297	173.461	94.3308	0.03
3:37:39 PM	44.0362	173.386	88.8547	0.03
3:37:49 PM	43.927	172.953	75.2487	0.03
3:37:59 PM	43.8257	172.52	71.861	0.03
3:38:09 PM	43.7399	172.255	70.7566	0.03
3:38:19 PM	43.7009	172.086	70.1736	0.03
3:38:29 PM	43.6619	171.889	69.8857	0.03
3:38:39 PM	43.6235	171.752	66.6978	0.03
3:38:49 PM	43.5377	171.508	53.2521	0.03
3:38:59 PM	43.5221	171.379	48.2911	0.03
3:39:09 PM	43.5065	171.148	46.4735	0.03
3:39:19 PM	43.4909	171.107	45.6879	0.03
3:39:29 PM	43.4519	171.012	45.1586	0.03
3:39:39 PM	43.3739	170.741	44.9873	0.03
3:39:49 PM	43.3115	170.66	44.6913	0.03
3:39:59 PM	43.2647	170.361	44.6368	0.03
3:40:09 PM	43.2413	170.252	44.5822	0.03
3:40:19 PM	43.2023	170.089	44.5433	0.03
3:40:29 PM	43.1867	169.695	47.2817	0.03
3:40:39 PM	43.1477	169.152	49.6559	0.03
3:40:49 PM	43.1817	168.801	50.65	0.03
3:40:59 PM	43.1895	168.474	50.7661	0.03
3:41:09 PM	43.1505	168.188	51.1221	0.03
3:41:19 PM	43.1165	167.805	51.127	0.03

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Time	Temperature (° F.) of Cold Water	Temperature (° F.) of Hot Water	Temperature (° F.) of Mixed Water	Pressure of water at mixing point
3:41:29 PM	43.1583	167.569	51.1453	0.03
3:41:39 PM	43.1506	166.683	51.1221	5.70
3:41:49 PM	43.1896	168.556	93.6402	5.33
3:41:59 PM	43.2442	169.31	137.937	5.51
3:42:09 PM	43.252	170.343	146.154	6.10
3:42:19 PM	43.3222	171.076	148.315	6.05
3:42:29 PM	43.3768	171.93	149.619	6.08
3:42:39 PM	43.4002	171.869	150.679	5.98
3:42:49 PM	43.4782	171.883	151.517	5.71
3:42:59 PM	43.5484	172.622	151.994	6.04
3:43:09 PM	43.6264	173.312	152.056	5.45
3:43:19 PM	43.681	173.387	151.635	0.03
3:43:29 PM	43.5328	173.238	76.0342	0.03
3:43:39 PM	43.4938	172.716	51.1144	0.03
3:43:49 PM	43.4626	172.628	46.7018	0.03
3:43:59 PM	43.2832	172.649	45.9164	0.03
3:44:09 PM	43.1896	170.696	54.4813	0.03
3:44:19 PM	43.1194	170.316	63.2646	0.03
3:44:29 PM	43.0884	170.621	62.9592	0.03
3:44:39 PM	43.0337	171.211	60.8798	0.03
3:44:49 PM	43.0259	171.116	60.5047	0.03
3:44:59 PM	42.9713	170.98	57.6287	0.03
3:45:09 PM	42.8933	170.919	56.1526	0.03
3:45:19 PM	42.8152	170.668	55.9295	0.03
3:45:29 PM	42.7528	170.315	55.7755	0.03
3:45:39 PM	42.7294	170.01	54.5354	0.03
3:45:49 PM	42.7684	170.566	54.7897	6.72
3:45:59 PM	42.7918	171.53	140.362	6.67
3:46:09 PM	42.8337	172.231	163.43	7.06
3:46:20 PM	42.8337	172.705	168.136	6.64
3:46:30 PM	42.8493	172.766	167.121	0.03
3:46:40 PM	43.1146	172.664	166.42	0.03
3:46:50 PM	43.3019	172.522	134.064	0.03
3:47:00 PM	43.2083	172.17	64.1372	0.03
3:47:10 PM	43.5281	171.919	65.7372	0.03
3:47:20 PM	43.5281	171.817	76.383	0.03
3:47:30 PM	43.5437	171.614	83.1848	0.03
3:47:40 PM	43.5671	171.485	84.8249	0.03
3:47:50 PM	43.5671	171.363	85.5247	0.03

FIG. **20** depicts a diagrammatic or schematic diagram of the test from which the above data were derived. In the test represented by the data of Table I and FIGS. **19**A-G, and as schematically depicted in FIG. **20**, a cold water line **910** from cold water supply **911** was coupled to a mixed water inlet **912**, a hot water line **914** from hot water supply **913** was coupled to mixed water inlet **912**. A diffuser **916** was coupled to mixed water inlet **912** so that hot and cold water flowed through mixed water inlet **912** and into diffuser **916**. A mixed water outlet **918** was coupled to diffuser **916** so that water flowing from the diffuser passed through outlet **918** toward a drain (not shown). Thermocouples **920**, **922**, **924**, were coupled to cold inlet, hot inlet, and mixed fluid outlet lines respectively to measure the temperature of the water flowing through each. A pressure sensor **926** was positioned in the hot water line to sense the pressure in the hot water. Thermocouples **920**, **922**, **924** and sensor **926** were coupled to computer **928** which recorded the data from each thermocouple, as depicted in Table 1 above. Valves **930** were positioned in each of the water lines to shut off or throttle flow of the hot, cold, and/or mixed water as necessary.

To simulate different stagnant hot fluid line temperatures that might be encountered in different settings, a starting mixed water temperature was arrived at by adjusting the hot **930***b* and cold **930***a* valves until a desired temperature was reached. For example, FIG. **19**A shows a starting mixed fluid temperature of about 85 degrees F. Once the desired starting temperature for the mixed water was achieved, all flow was simultaneously shut off. Then, the hot water valve **930**b was opened full-open to simulate the hot water displacing the stagnant water in the hot water line. Mixed water temperature in the mixed water outlet line was recorded via thermocouple **924** (shown in the fourth column). Cold and hot water temperatures were recorded via thermocouples **920** and **922** in the cold and hot water lines respectively, those temperatures shown in the second and third columns respectively. The time of day each reading was made is indicated in the first column, each entry separated from the prior entry by ten seconds. The pressure, represented in the fifth column, was recorded in the hot water line, is shown in pounds per square inch gauge (psig), and serves to indicate when the hot water was opened to the full-open position.

Thermocouple **920** was about 6 feet away from the point where cold inlet line **910** connects to mixed inlet line **912**, and thermocouple **922** was about 6 feet away from the point where hot inlet line **914** connects to mixed inlet line **912** (each distance of about 6 feet including about 2 feet of rubber hose). Thermocouple **924** and sensor **926** were about 5 feet away (about 3 feet of which was rubber hose) from the point where diffuser **916** connects to mixed outlet line **918**.

FIGS. **19**A through G represent graphically certain data from Table 1. Data were taken at ten (10) second intervals. The mixed water temperature is observed to increase to a local maximum in each of the graphs depicted in FIGS. **19**A through G. The starting temperature of the mixed water was controlled by adjusting the hot valve while leaving the cold valve in the full-open position to achieve a desired starting mixed water temperature. The gradual increase in mixed water temperature, compared to plug flow through a single pass of pipe resulting in a nearly immediate jump to hot water of equal temperature with the temperature of the hot water in the water heater tank, demonstrates the effects of the diffuser.

Although this invention has been described and illustrated in detail with reference to certain illustrative embodiments, variations and modifications exist within the scope and spirit of the invention as described and defined in the following claims.

The invention claimed is:

1. A decontamination apparatus comprising:

a fluid heater,

a cold fluid supply line,

a hot fluid supply line for supplying hot fluid from the fluid heater to a thermostatic mixing valve,

the thermostatic mixing valve having a hot fluid inlet for receiving fluid from said heater, a cold fluid inlet for receiving fluid from the cold fluid supply line, and a mixed fluid outlet for supplying fluid to a mixed fluid supply line;

a restrictor adapted and configured for creating a pressure drop in the cold fluid supply line;

an emergency fixture connected to the mixed fluid supply line for supplying fluid therefrom to a user and configured to deliver the mixed fluid at a flow rate and pattern to at least a portion of the user's body, and

a diffuser containing fluid and coupled between the hot fluid supply line and the thermostatic mixing valve for mixing fluid within the diffuser with fluid received from the mixed fluid outlet.

2. The apparatus of claim **1**, wherein said restrictor comprises one or more pressure reducing valves.

3. The apparatus of claim **1**, which further comprises a support supporting said fluid heater, said mixing valve, and said emergency fixture.

4. The apparatus of claim **1**, wherein said fluid heater is an electric heater.

5. The apparatus of claim **1**, wherein the diffuser includes a first fluid conduit and at least a second fluid conduit, a majority of the first fluid conduit being surrounded by the second fluid conduit, the first and second conduits being coupled together to cause fluid to flow into the first conduit from the mixed fluid outlet, pass through the first conduit, and into fluid outside the first conduit and in the second conduit.

6. The apparatus of claim **5**, wherein the first conduit is formed to include a plurality of apertures, the first and second conduits are coupled together, and a first portion of the fluid flows through the plurality of apertures and a second portion of the fluid flows from the first conduit through an end of the first conduit into fluid outside the first conduit and in the second conduit.

7. The apparatus of claim **1**, wherein said emergency fixture is a drench shower having fluid outlets directed at least partially downwardly.

8. The apparatus of claim **1**, wherein the at least one means for restricting flow comprises one or more restrictors.

9. The apparatus of claim **1**, wherein the at least one means for restricting flow comprises one or more pressure reducing valves.

10. The apparatus of claim **1**, further comprising a second thermostatic mixing valve having a hot fluid inlet for receiving fluid from the hot fluid supply line, a cold fluid inlet for receiving fluid from the cold fluid supply line, and a mixed fluid outlet for supplying fluid to a mixed fluid supply line through which one, the other, or both of the hot and cold fluids flow from the second thermostatic mixing valve.

11. The apparatus of claim **1** wherein the pressure drop is of the fluid in the first fluid inlet relative to the pressure of the fluid of said source.

12. The apparatus of claim **1** wherein said restrictor decreases the pressure difference between the pressure at the hot fluid inlet relative to the pressure at the cold fluid inlet.

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